Future Ocean, Kiel Marine Sciences
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World metal production and future demands

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„Mineral supply for the German industry has a high priority for us. Moving the German Mineral Resources Agency to Berlin is a consequent next step.“
Securing raw material supply for Germany

Aim

A Improve market transparency in the mineral resources sector by providing minerals information and analysis and advise companies about price and supply risks
B Professional backing of measures taken by the German government and companies to secure raw materials supply

Services

Raw Materials Information and Analyses
1. Raw Material Information System
2. Risk Assessment
3. Raw Material Potentials

Contributions to a secure raw materials supply
4. Strategies for Security of Supply
5. Diversifying Supply

Network Building, Raw Material Dialogues, Industry Workshops, Conferences
1. Future Demand
   Industrialization
   Influence of emerging technologies

2. Future Supply
   Major supply sources

3. Which raw materials are critical?
   Price and supply risks

4. Outlook for copper, terrestrial and marine – some thoughts
Future Demand
Cyclical raw material markets: Price and GDP

CRB Metals Sub-Index

1. Oil price shock
2. Oil price shock
Collaps of USSR
Asian crisis
China Factor

GDP growth world (%)

Indexwert

Collaps of Bretton-Woods
High demand


nominal real, basis: 2000

Reuters CRB-Metals-Subindex copper-, steel- and lead scrap, zinc, tin

Quelle: BGR Datenbank, CRB, World Bank
Average share of demand of the BRIC states of global demand for aluminium, steel, copper, zinc and tin

University of Bonn, M. Stürmer, study commissioned and funded by DERA, 2012
Average share of demand of Industrialised Nations of global demand for aluminium, steel, copper, zinc and tin

University of Bonn, M. Stürmer, study commissioned and funded by DERA, 2012
<table>
<thead>
<tr>
<th>Raw material</th>
<th>2006*</th>
<th>2030*</th>
<th>Emerging Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallium</td>
<td>0,18</td>
<td>3,97</td>
<td>Thin layer photovoltaics, IC, WLED</td>
</tr>
<tr>
<td>Indium</td>
<td>0,40</td>
<td>3,29</td>
<td>Displays, Thin layer photovoltaics</td>
</tr>
<tr>
<td>Scandium</td>
<td>low</td>
<td>2,31</td>
<td>SOFC Fuel cells, Al-alloys</td>
</tr>
<tr>
<td>Germanium</td>
<td>0,28</td>
<td>2,20</td>
<td>Fibre optic cable, IR optical technology</td>
</tr>
<tr>
<td>Neodym</td>
<td>0,23</td>
<td>1,66</td>
<td>Permanent magnets, laser technology</td>
</tr>
<tr>
<td>Platinum</td>
<td>low</td>
<td>1,35</td>
<td>Fuel cells, catalysts</td>
</tr>
<tr>
<td>Tantalum</td>
<td>0,40</td>
<td>1,02</td>
<td>Micro capacitors, medical technology</td>
</tr>
<tr>
<td>Silver</td>
<td>0,28</td>
<td>0,83</td>
<td>RFID, lead free solders</td>
</tr>
<tr>
<td>Tin</td>
<td>0,57</td>
<td>0,71</td>
<td>Lead free solders, transparent electrodes</td>
</tr>
<tr>
<td>Cobalt</td>
<td>0,21</td>
<td>0,43</td>
<td>Lithium ion batteries, synthetic fuels</td>
</tr>
<tr>
<td>Palladium</td>
<td>0,09</td>
<td>0,29</td>
<td>Catalysts, seawater desalination</td>
</tr>
</tbody>
</table>

Future Demand - The influence of emerging technologies: Breakthrough difficult to predict

Expected increases in demand for selected raw materials in correlation to current supply and corresponding supply risks

(source: Tercero Espinoza: „The role of emerging technologies in a rapidly changing demand for mineral raw materials“, Polinares WP2)

POLINARES Final Conference 28th November 2012
Future Supply
Static lifetime of reserves and resources – a dynamic system

Copper

- 1960: 4.2 Mio. t
- 2008: 14.4 Mio. t

- 1987: 39 years
- 2008: 36 years

Nickel

- 1960: 0.34 Mio. t
- 2008: 1.5 Mio. t

- 1987: 63 years
- 2008: 46 years

Indium

- 1972: 66.4 t
- 2007: 563 t

- 1989: 15 years
- 2007: 19 years

Cobalt

- 1960: 14.734 t
- 2008: 63.783 t

- 1988: 125 years
- 2008: 111 years

Source: USGS, BGR database, 2009

Legend:
- Pink: Static lifetime of reserve base
- Blue: Mine production (Indium: refined production)
- Orange: Static lifetime of reserves
Global supply – What are the major mining countries?
Major mining countries of the world

Major mining countries in the world* by value
Share of global mine production >5 %, countries represent ca. 50-55 % of the total value

* Metals, diamonds, zircon, P, K2O, B, Li, incl. U

Data source: Raw Materials Group Stockholm, Mines Value 2008, 75 % coverage
Major mining countries in the world* by value
Share of global mine production >1 %, countries represent ca. 60-65 % of the total value

- 5 - 10 %
- 1 - 5 %

* Metalle, Diamanten, Zirkon, P, K2O, B, Li, inkl. U
RMG Mines Value 2008, 75 % Datenerfassung
Major mining countries of the world* by value
Share of global mine production >0,1 %, countries represent ca. 80-85 % of the total value

* Metalle, Diamanten, Zirkon, P, K2O, B, Li, inkl. U  
RMG Mines Value 2008, 75 % Datenerfassung
Global exploration budgets and CRB-Metals-Sub-Index

Exploration budgets [bn US$]

CRB Metals-Sub-Index

Data Source: Metals Economics Group (MEG), CRB
Which raw materials are critical?
Methodology: Global concentration of supply (Herfindahl-Hirschman-Index, HHI)

Rare Earths: Global concentration of mine production

- **China**
  - 2010: 118,900 t SEO
  - 97% of global production

- **Russia**
  - 2010: 1,495 t SEO

- **USA**
  - 2010: 1,483 t SEO from dumps

- **Brazil**
  - 2010: 1,043 t Monazite

- **India**
  - 2009: 35 t SEO

**Methodology: Global concentration of supply (Herfindahl-Hirschman-Index, HHI)**

**DERA Risk Assessment for Mineral Supply**

**Russia**
- 2010: 1,495 t SEO

**Brazil**
- 2010: 1,043 t Monazite

**India**
- 2009: 35 t SEO

**China**
- 2010: 118,900 t SEO
  - 97% of global production
  - HHI = 9,520
Methodology: Weighted country risk (GLR) by World Governance Indicators

World Governance Indicators by World Bank:

- Control of Corruption
- Voice and Accountability
- Political Stability and Absence of Violence
- Government Effectiveness
- Regulatory Quality
- Rule of Law

DERA study on critical raw materials – Highlight Cu, Ni, Mn, Mo

Herfindahl-Hirschman-Index of production 2009/2010 (country concentration)
Assessing the long-term supply risks for mineral raw materials—a combined evaluation of past and future trends

Dirk Rosenau-Tornow, Peter Buchholz, Axel Riemann, Markus Wagner

\(^a\) Volkswagen AG, Group Research, Environmental Affairs Product, Letter Box 1774, 38436 Wolfsburg, Germany
\(^b\) Federal Institute for Geosciences and Natural Resources (BGR), Section Mineral Economics, Stilleweg 2, 30655 Hannover, Germany
Outlook for copper
Copper mine production 2010

Kanada 3%
USA 7%
Peru 8%
Chile 34%
Polen 3%
Russische Förderung 4%
Kasachstan 2%
China 7%
DR Kongo 2%
Indonesien 5%
Sambia 4%
Australien 5%
Übrige Länder / n.a. 14%

Quelle: BGR Datenbank
Copper mine production 2010 and country risk

Quelle: BGR Datenbank
Country and company concentration of copper mine production
Distribution of copper reserves 2010

Quelle: USGS
Future Production – annual mine capacity until 2017

Data source: Metals Economic Group
# The ten largest copper projects (total, all cooper projects until 2017: 9.6 Mt Cu)

<table>
<thead>
<tr>
<th>Name</th>
<th>Firma</th>
<th>Land</th>
<th>Status</th>
<th>Typ</th>
<th>Erwartete Jahresförderkapazität [1.000 t Cu]</th>
<th>Reserven &amp; Ressourcen [Mio. t Inh.]</th>
<th>Erwarteter Produktionsbeginn</th>
<th>Betriebskosten [US$/lb]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>Rio Tinto</td>
<td>USA</td>
<td>Feasibility</td>
<td>UG</td>
<td>500</td>
<td>23,9</td>
<td>2021</td>
<td>k. A.</td>
</tr>
<tr>
<td>Oyu Tolgoi</td>
<td>Rio Tinto</td>
<td>Mongolei</td>
<td>im Bau</td>
<td>OP</td>
<td>450</td>
<td>31,5</td>
<td>2013</td>
<td>0,45</td>
</tr>
<tr>
<td>Tampakan</td>
<td>Xstrata</td>
<td>Philippinen</td>
<td>Feasibility</td>
<td>OP</td>
<td>450</td>
<td>15,1</td>
<td>2019</td>
<td>0,46</td>
</tr>
<tr>
<td>Congo Mines and Infrastructure Construction*</td>
<td>China Railway Engineering</td>
<td>DR Kongo</td>
<td>Feasibility</td>
<td>OP</td>
<td>400</td>
<td>6,8</td>
<td>2013</td>
<td>k. A.</td>
</tr>
<tr>
<td>El Pachon</td>
<td>Xstrata</td>
<td>Argentinien</td>
<td>Feasibility</td>
<td>OP</td>
<td>400</td>
<td>15,5</td>
<td>2016</td>
<td>0,50</td>
</tr>
<tr>
<td>Las Bambas</td>
<td>Xstrata</td>
<td>Peru</td>
<td>im Bau</td>
<td>OP/ UG</td>
<td>400</td>
<td>10,5</td>
<td>2014</td>
<td>0,60</td>
</tr>
<tr>
<td>Golpu</td>
<td>Newcrest Mining</td>
<td>Papua-Neuguinea</td>
<td>Prefeasibility</td>
<td>UG</td>
<td>330</td>
<td>k. A.</td>
<td>2019</td>
<td>k. A.</td>
</tr>
<tr>
<td>Pebble</td>
<td>Northern Dynasty Minerals/ Anglo American/ Xstrata</td>
<td>USA</td>
<td>Prefeasibility</td>
<td>OP/ UG</td>
<td>307</td>
<td>32,4</td>
<td>2019</td>
<td>-0,11</td>
</tr>
<tr>
<td>Frieda River</td>
<td>Xstrata</td>
<td>Papua-Neuguinea</td>
<td>Feasibility</td>
<td>OP</td>
<td>304</td>
<td>12,8</td>
<td>2017</td>
<td>0,43</td>
</tr>
<tr>
<td>La Granja</td>
<td>Rio Tinto</td>
<td>Peru</td>
<td>Prefeasibility</td>
<td>OP</td>
<td>300</td>
<td>18,4</td>
<td>2017</td>
<td>0,47</td>
</tr>
</tbody>
</table>

* Dikuluwe- und Mashamba-Konzession
Expected future supply for copper until 2017

- sekundäre Raffinadeproduktion
- Bergwerksförderung bis 2010
- geplante zusätzliche Bergwerksförderung bis 2017
- Raffinadeverbrauch bis 2010
- Raffinadeverbrauch Wachstumsrate 5,2%
- Raffinadeverbrauch Wachstumsrate 2,6%
Future Demand – Industrialisation: Asia as a driver

Demand for copper per world region
(low/high growth scenario, by ENERDATA)

(source: Keramidas, Kitous, Griffin: „Future availability and demand for oil gas and key minerals“, Polinares WP2
POLINARES Final Conference 28th November 2012)
Terrestrial and marine mining - some thoughts
Terrestrial and marine mining – some thoughts

Copper, simple estimate (dimensions)

<table>
<thead>
<tr>
<th>Mine Production (One mine)</th>
<th>Grade</th>
<th>Annual Mine capacity</th>
<th>Annual metal production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn-nodules CCZ</td>
<td>Cu, 1.18 %</td>
<td>2.0 Mt* (ore, dry)</td>
<td>21,000 t (metal)</td>
</tr>
<tr>
<td></td>
<td>wet ore 30 % moist. mine loss</td>
<td>Recovery 90 %??</td>
<td></td>
</tr>
<tr>
<td>Terrestrial e.g. Las Bambas, Peru</td>
<td>Cu, 0.5 %</td>
<td>100 Mt (ore)</td>
<td>405,000 t (metal)</td>
</tr>
<tr>
<td></td>
<td>Mine loss 10 %</td>
<td>Recovery 90 %</td>
<td></td>
</tr>
</tbody>
</table>

*marine: range 1.5-4.0 Mt annual mine capacity, International Seabed Authority, Hein et al, 2013 and others
Terrestrial and marine mining – some thoughts

### Nickel, simple estimate (dimensions)

<table>
<thead>
<tr>
<th>Mine production</th>
<th>Grade</th>
<th>Annual Mine capacity</th>
<th>Annual metal production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn-nodules CCZ</td>
<td>Ni, 1.39 %</td>
<td>2.0 Mt (ore, dry)</td>
<td>21,000 t (metal)</td>
</tr>
<tr>
<td></td>
<td>wet ore 30 % moist. mine loss</td>
<td>Recovery 90 %?</td>
<td></td>
</tr>
<tr>
<td>Terrestrial e.g. Ambatovy Madagascar</td>
<td>Ni, 1.04 %</td>
<td>8 Mt (ore, lat.)</td>
<td>50,000 t (metal)</td>
</tr>
<tr>
<td></td>
<td>Mine loss 10 %</td>
<td>Recovery 70 %</td>
<td></td>
</tr>
</tbody>
</table>

*marine: range 1.5-4.0 Mt annual mine capacity, International Seabed Authority, Hein et al, 2013 and others*
Average cash costs for copper (terrestrial)

Cash operating costs and price for marine Mn-nodules ??

Combined Cu, Ni, Mo, (Mn and others)
Future Ocean, Kiel Marine Sciences  
March 20, 2013

World metal production and future demands

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Federal Institute for Geosciences and Natural Resources (BGR), Berlin, Germany