Strategic & Critical Minerals – A Global Perspective

Energy Critical Elements – Securing Materials for Emerging Technologies

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Nevada Bureau of Mines and Geology

* with help from Murray Hitzman, Colorado School of Mines
1. Critical and strategic minerals will change with time.
2. Demand is high.
3. China will be a major force in the world of strategic and critical minerals.
4. The U.S.A. has the right geology to be a major force as well for many, but not all, minerals.
Critical and strategic minerals will change with time.
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$\text{CuIn}_x\text{Ga}_{(1-x)}\text{Se}_2$ or CIGS, for solar panels?
CdTe, GaAs, and Ge for solar panels?
Nd, Dy for magnets for wind and other electrical turbines?
Li and V for different types of batteries?
A 2011 policy-oriented study by the American Physical Society and the Materials Research Society – concerning the availability of minerals needed for new energy technologies.

Robert Jaffe, MIT, Chair
Jon Price, NBMG, Co-Chair
The underlying issue: Increasing worldwide demand for energy, mineral resources, food, etc.

Historical and projected use of energy

EIA, 2010
Both world population and average standard of living keep rising.
Global copper production in 2010 (16.2 million metric tons) nearly equaled over 100 years of production from the Bingham Canyon mine (17.0 million metric tons).
Definition:

**Energy-critical elements (ECEs)** are a class of chemical elements that currently appear **critical to** one or more **new energy-related technologies**. A shortage of these elements would significantly inhibit large-scale deployment, which could otherwise be **capable of transforming the way we produce, transmit, store, or conserve energy**. We reserve the term ECE for chemical elements that have **not been widely extracted, traded, or utilized in the past**, and are therefore not the focus of well-established and relatively stable markets.
Some ECEs today
New Energy Technologies

- Renewable
- CO₂ neutral

Tellurium
Indium
Gallium
Germanium

Terbium
Europium

Neodymium
Dysprosium
Praseodymium
Samarium

Helium

Lithium
Lanthanum
Constraints on availability of ECEs

A. Crustal abundance, concentration, and distribution
B. Geopolitical risk
C. Risks of joint production
D. Environmental and social concerns
E. Response times in production and utilization
ECEs – less common and more expensive
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China is the Number One Producer for 25 of these 46 items and in the top three for 31.
China has approximately 20% of the world’s population.

Commodities for which China produced >20% of the world’s total in 2010:

- Aluminum*, 41%
- Cadmium, 25%
- Diatomite, 25%
- Indium, 52%
- Lead, 43%
- Molybdenum, 40%
- Tin, 44%
- Zinc, 29%
- Arsenic, 46%
- Cement, 55%
- Germanium*, 67%
- Iron ore, 38%
- Manganese, 22%
- Phosphate, 37%
- Tungsten, 85%
- Barite, 52%
- Coal, 44%
- Gypsum, 31%
- Steel*, 45%
- Mercury, 79%
- Rare Earths, 97%
- Vanadium, 41%

*refined, not mined

Data sources: USGS, EIA, CIA
World’s leading rare earth producer (China, 97%)  
Countries with 4% or more of global production - none  
Other countries with production or major reserves

Rare earth elements – significant current supply risk
OUR CONSULTANT WILL TELL US HOW WE CAN SECURE A LONG-TERM SUPPLY OF RARE EARTH METALS FOR OUR PRODUCTS.

CHINA HAS MOST OF THE RARE EARTH METALS. TRY DYING AND REINCARNATING. THERE'S A 20% CHANCE THAT YOU'LL BE BORN CHINESE.

WHAT'S PLAN B?

IF THE ONLY PART THAT GOES WRONG IS THE CHINESE PART, YOU CAN TRY DYING AGAIN.
World’s leading platinum producer (South Africa, 75%)

Countries with 4% or more of global production

Other countries with production or major reserves

Platinum – possible supply risk

Data source: USGS
Constraints on availability of ECEs

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ECEs that are byproducts from Cu-Mo from Cu from Cu-Mo from Zn from several metals from Zn from Al from natural gas from Se from Cu from natural gas

Source of data: USGS, EIA, CRC Handbook of Chemistry and Physics, others
<table>
<thead>
<tr>
<th></th>
<th>Main product</th>
<th>Byproduct</th>
<th>Byproduct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cu</td>
<td>Se</td>
<td>Te</td>
</tr>
<tr>
<td>Global production (metric tons)</td>
<td>16,200,000</td>
<td>2,260</td>
<td>~500</td>
</tr>
<tr>
<td>Price ($/kg)</td>
<td>$7.54/kg</td>
<td>$77.16/kg</td>
<td>$210/kg</td>
</tr>
<tr>
<td>Value of global production ($)</td>
<td>$122 \times 10^9</td>
<td>$174 \times 10^6</td>
<td>$105 \times 10^6</td>
</tr>
<tr>
<td>Ratio of values of global production</td>
<td>Cu:Se = 700:1</td>
<td>Cu:Te = 1200:1</td>
<td></td>
</tr>
</tbody>
</table>

Securing more mineral resources that are recovered as byproducts will require either exploration for new types of resources or research on metallurgical extraction.

2010 data from USGS
Constraints on availability of ECEs

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Collapsed shaft in the street by the school in Virginia City, Nevada (circa 1995, from mining in the late 1800s) – The principal’s car went into the “sinkhole.”
World’s leading cobalt producer (Democratic Republic of Congo, 51%)

Countries with 4% or more of global production

Other countries with production or major reserves

(China = 7%)

Data source: USGS
Environmental and Social Concerns

- Decades of increasing vigilance in mining industry with respect to environmental and social issues

- Generally high environmental and social standards in the developed world.

- Rising worldwide social and environmental sustainability standards
  - International Council on Mining and Minerals (ICMM)
  - International Finance Corp (IFC)
  - World Bank
  - Major lending banks

The major companies are acting responsibly.

Galamsey (artisanal, subsistence miners) at Kyereboso, Ghana, 2008 - not a major company
Constraints on availability of ECEs

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Time to plan, research, develop, fund, permit, and deploy

Exploration to mining: 5 to 15+ years
New technology for producing, transmitting, storing, or conserving energy: also 5 to 15+ years or even decades
Findings and Recommendations

Information

The United States government should gather, analyze, and disseminate information on energy-critical elements across the life-cycle supply chain including discovered and potential resources, production, use, trade, disposal, and recycling. The entity undertaking this task should be a “Principal Statistical Agency” with survey enforcement authority.

The federal government should regularly survey emerging energy technologies and the supply chain for elements throughout the periodic table, with the aim of identifying critical applications as well as potential shortfalls.
Findings and Recommendations

Research, development, and workforce issues

The federal government should establish a research and development effort focused on energy-critical elements and possible substitutes that can enhance vital aspects of the supply chain including: geological deposit modeling, mineral extraction and processing, material characterization and substitution, utilization, manufacturing, recycling, and life-cycle analysis.
Findings and Recommendations

The role of material efficiency

Steps should be taken to improve rates of post-consumer collection of industrial and consumer products containing ECEs, beginning with an examination of the numerous methods being explored and implemented in various states and countries.
Findings and Recommendations

Possible market interventions

With the exception of helium, the Committee does not propose government interventions in markets beyond those contained in the other recommendations concerning research and development, information gathering and analysis, and recycling. In particular, the Committee does not recommend nondefense-related economic stockpiles.

Helium is unique even among ECEs. We concur with and reiterate the APS Helium Statement of 1995: “Measures should be adopted that will both conserve and enhance the nation’s helium reserves. Failure to do so would not only be wasteful, but would also be economically and technologically shortsighted.”
1. Critical and strategic minerals will change with time.
2. Demand is high.
3. China will be a major force in the world of strategic and critical minerals.
4. The U.S.A. has the right geology to be a major force as well for many, but not all, minerals.
Conclusions from the report

• We are not facing an imminent absolute shortage of energy critical elements (Hubbard’s Peak scenario).

• However, market-driven shortages are possible (happening today).

• No country can become “ECE independent.”

• Securing ECEs will require both

  *Aggressive research (geological, metallurgical, materials science) and*
  
  *Free markets.*
## REEs — Chinese Export Quotas

<table>
<thead>
<tr>
<th>Year</th>
<th>Quota</th>
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<tbody>
<tr>
<td>2005</td>
<td>65,609 t REO*</td>
</tr>
<tr>
<td>2006</td>
<td>61,821 t REO</td>
</tr>
<tr>
<td>2007</td>
<td>59,643 t REO</td>
</tr>
<tr>
<td>2008</td>
<td>56,643 t REO</td>
</tr>
<tr>
<td>2009</td>
<td>50,145 t REO</td>
</tr>
<tr>
<td>2010</td>
<td>30,258 t REO</td>
</tr>
<tr>
<td>(first half 2011)</td>
<td>14,508 t REO</td>
</tr>
</tbody>
</table>

*REO = rare earth oxides

- **Quota**: Domestic + foreign companies
- **2008**: Adjusted to an equivalent 12 month quota as there was a change in the dates for which they applied
We exclude carbon (as coal, oil, natural gas) and uranium, since they have been the subject of many studies and mature regulation; moreover, increased demand does not create novel issues for these elements beyond those already explored in the economic, technical, and political arenas. We exclude elements like phosphorus and potassium, for which we can see only peripheral relevance to energy issues.
Many important elements are notably absent from this list. Copper, aluminum, iron, tin, and nickel are absolutely essential for energy applications. However, because they enjoy large, mature, and vigorous markets with many suppliers, a strong demand from the energy sector would most likely be met with a market-driven increase in supply.
Copper resources are broadly distributed.

Data source: USGS
There is a general trend that rarer elements are more expensive than common elements.

Source of data: USGS, EIA, CRC Handbook of Chemistry and Physics, others
The USA is the Number One Producer for 2 of these 46 items and in the top three for 13.

Source of data: USGS, EIA, CRC Handbook of Chemistry and Physics, others.
This report surveys potential constraints on the availability of ECEs and then identifies five specific areas of potential action by the United States to insure their availability:

1) federal agency coordination;
2) information collection, analysis, and dissemination;
3) research, development, and workforce enhancement;
4) efficient use of materials; and,
5) market interventions.
Thank you!

Energy Critical Elements:

Securing Materials for Emerging Technologies
A REPORT BY THE APS PANEL ON PUBLIC AFFAIRS & THE MATERIALS RESEARCH SOCIETY