Resource Constraints on Alternative Energy Development

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Alternative Energy Technologies

Solar Power
  Photovoltaics
  Concentrating Solar Power (CSP)

Power Storage (Batteries)

Hybrid & “Green” Vehicles
Photovoltaic Technologies

- Silicon
  - High-purity Silica
- CIGS
  - Copper – Indium – Gallium - diSelenide
- Cd-Te
  -- Cadmium - Tellurium
A. High-Purity Silicon

B. Cadmium-Tellurium

Tellurium

Vulcanizing rubber

Copper & Stainless Steel alloys

Newest Flash Memory Devices of Antimony-Germanium-Tellurium

Te-based Thermoelectric Coolers
CIGS

Liquid Crystal Displays (LCDs), flat panel displays, optical coatings, light-emitting diodes (LEDs) antistatic coatings, strain gauges, gas sensors.

Light-emitting diodes (LED’s)

Power amplifiers for cell phones
Concentrating Solar Power (CSP)

Reflector material is Aluminum or Silver

Tube material ..... Several possible
Power Storage

Necessary for non-baseload power sources

Keep power for nights with no sunlight,

Days with no wind.
Utility-Scale Batteries
What’s in them?

<table>
<thead>
<tr>
<th>Type</th>
<th>Ingredients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vanadium Redox</td>
<td>Vanadium</td>
</tr>
<tr>
<td>Zn-Ce and Zn-Br</td>
<td>Zinc, Cerium, Bromine</td>
</tr>
<tr>
<td>Lead Acid</td>
<td>Lead</td>
</tr>
<tr>
<td>Ni – MH</td>
<td>Rare Earth Elements, Nickel</td>
</tr>
<tr>
<td>Lithium-ion</td>
<td>Cobalt, Manganese, Lithium</td>
</tr>
<tr>
<td>Dry-charge</td>
<td>Lead, Antimony, Arsenic, Calcium, and Tin</td>
</tr>
</tbody>
</table>
Hybrids

Battery pack
Currently NiMH batteries from Sanyo and Panasonic

16 kg Ni + Co + REE in battery
Nd, Bo, Co, Cu in generator & motor
45 kg Cu (twice as much) for wiring

Cobalt consumption is significant, but exact numbers are unavailable.
Fuel Cell Vehicles

All currently require PGMs (Platinum Group Metals) as catalyst

- Petroleum-refining catalysts
- Catalytic converters
- Hard disk drives
- Hi-temp applications
- Jewelry & bullion
- Fiberglass manufacture
- Spark plug tips
Hot List

Indium  Cobalt  Lead
Gallium  Zinc  Tellurium
Selenium  Vanadium  Silver
Bromine  Platinum Group Metals
Rare Earth Elements  Copper  Manganese  Aluminum  Aluminum
Hot List Import Sources

Indium ............ China
Gallium ......... China, Russia, Ukraine
Rare Earths..... China
Platinum Group ..Russia, Ukraine, Canada, S. Africa
Tellurium ........ Central Africa
Selenium ....... Central Africa, Canada, Philippines
Vanadium ....... Swaziland, Central Africa
Zinc ............... Peru, Canada, Mexico
Silver ............. Mexico, Canada, Peru
Alumina ......... Guinea, Brazil, Australia, Jamaica
Manganese ....... S. Africa, Gabon, Australia, China
Cobalt ............. Congo (through China)
Some Price Histories

**Indium**

- Price in $/pound

**Gallium**

- Price in $/pound

**Tellurium**

- Price in $/pound

**Platinum Group Metals (PGM)**

- Price in $/ounce

**Platinum**

- Price in $/ounce

**Palladium**

- Price in $/ounce
Avg Annual Base Metal Prices

Year
1991 1993 1995 1997 1999 2001 2003 2005 2007

Price ($US)
0 1 2 3 4

Lead
Zinc
Copper

Average annual price of silver (US$)

$ per ounce
$0.00 $2.00 $4.00 $6.00 $8.00 $10.00 $12.00 $14.00 $16.00 $18.00 $20.00


Price History of Other Metals For Alternative Energy
How much?

<table>
<thead>
<tr>
<th>Photovoltaics</th>
<th>Tellurium use</th>
<th>6 g/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gallium use</td>
<td>0.5 g/m²</td>
</tr>
<tr>
<td></td>
<td>Indium use</td>
<td>3 g/m²</td>
</tr>
<tr>
<td></td>
<td>Selenium use</td>
<td>5 g/m²</td>
</tr>
</tbody>
</table>

With 10% efficiency, 1.4 MW per $10^4$ meters², estimated resource needs per MW would be

- 42 kg Te for Cd-Te
- (independent source quotes 135 kg/MW)
- 3.5 kg Ga +
- 21 kg In +
- 35 kg Se for CIGS

Ref: NREL Report to National Research Council
Annual world production

(Estimated, as much information is proprietary.)

Tellurium – 200,000 kg (est.)
Gallium - 80,000 kg
Indium - 510,000 kg
Selenium – 1.5 million kg

Cd-Te ... 42 kg Te – 0.02% annual production per mW

CIGS .... 3.5 kg Ga - 0.004% per mW
... 21 kg In - 0.004% per mW
Colorado Energy Forum estimates the State will require 4900 additional megaWatts by 2025.

Photovoltaic power will require thousands of kilograms of critical/strategic minerals.

Wind power generator requires an estimated 1 metric ton copper/megaWatt.
Conclusions

Development of alternative energy technologies requires scarce strategic metals.

Development of these technologies may be constrained by supply and price issues with these metals.

Achieving energy independence by means of alternative energy technologies can’t be done without domestic mining.

Moving to renewable energy technologies is inconsistent with anti-mining advocacy.