Resource Constraints
On
Alternative Energy Development

Jim Burnell
Colorado Geological Survey
Alternative Energy Technologies

Solar Power
  Photovoltaics
  Concentrating Solar Power (CSP)

Power Storage (Batteries)

Hybrid & “Green” Vehicles
Photovoltaic Technologies

3 leading technologies

- **Cd-Te**
  -- Cadmium – Tellurium

- **CIGS**
  – Copper – Indium – Gallium – Selenide
  ( + Germanium)

- **Silicon**
  – Ultra High-purity Silica
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
Germanium
- Fibre optics
- Infrared optics
- Low-reflectivity industrial glass
- Catalysis (PET plastics)
- Al and Be alloys
- High-speed Si-Ge integrated circuits

Silicon
Ultra-high purity quartz derived from pegmatite deposits.
Primary Import Sources

Tellurium, Germanium, Gallium, Indium
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>Components</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 – Metal Hydride</td>
<td>Rare Earth Elements (REE), Nickel, Cobalt</td>
</tr>
<tr>
<td>Lithium-ion</td>
<td>Cobalt, Manganese, Lithium</td>
</tr>
</tbody>
</table>
Level of Import Dependence

- Vanadium
- Lead
- Zinc
- Bromine
- Cerium
Primary Import Sources

Zinc  Bromine  Lead  Vanadium  Cerium
Price Histories

- Vanadium
- Lead
- Zinc
- Bromine
- Cerium

Price $/pound

2003 peak

Current
Hybrid cars
Hybrid Technology Options

Nickel Metal Hydride
- Honda Accord hybrid
- Civic hybrid
- Ford Escape hybrid
- Toyota Prius

Lithium-Ion
- Chevy Volt
- Nissan
- Volvo
- Ford
- BMW
Ni-MH Technology

Favored formulation:

REE (La, Ce, Nd, Pr) + Ni, Co, Mn

Alternative formulations:

Ti/V + Ni, Cr, Co, Fe or Mn
How much in a Prius?

Estimates from industry and trade group sources:

3.2 pounds cobalt

25 pounds nickel

30-32 pounds REE
  (La + Nd + Dy + Sm)

100 pounds Cu
  (twice as much as standard)
Primary Import Sources

Copper
Manganese
Nickel
Cobalt
Rare Earths
Rare Earth Elements
2013 Projections

Supply | Demand
---|---
Lanthanum | 54,000 t/yr | 59,000 t/yr
Neodymium | 39,500 t/yr | 36,000 t/yr

China is expanding manufacturing to use up their supply, including Nd-Fe-B magnets for wind turbine generators.

Prediction: China will use all they mine internally in 2 years.
REE Supply/Demand
A story of China vs. the World

Source: Great Western Minerals Group
Lithium-ion Technology

Picked by many to supplant Ni-MH as primary technology. Historically, Li-Ion has trailed Ni-MH in durability, safety, cost.

Various formulations:

- Lithium – Cobalt
- Lithium-Iron-Phosphate
- Lithium - Manganese
Continental Brines

Magnesium content is a key for extraction of Lithium from brines. Higher Mg = more time & $$.

also important: evaporation rate, politics.

<table>
<thead>
<tr>
<th>Deposit</th>
<th>% Lithium</th>
<th>Mg/Li Ratio</th>
<th>Reserves (est)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atacama (Chile)</td>
<td>0.15</td>
<td>6.4</td>
<td>3 million m ton</td>
</tr>
<tr>
<td>Hombre Muerto (Argentina)</td>
<td>0.062</td>
<td>1.37</td>
<td>2 million m ton</td>
</tr>
<tr>
<td>Uyuni (Bolivia)</td>
<td>0.028</td>
<td>19.9</td>
<td>5.4 million m ton</td>
</tr>
</tbody>
</table>
How much?

Photovoltaics

- Tellurium use: 6 g/m²
- Gallium use: 0.5 g/m²
- Indium use: 3 g/m²
- Selenium use: 5 g/m²

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.

Colorado is 27th in nation in the amount of electrical power generated.

Photovoltaic power will require thousands of kilograms of critical/strategic minerals.
It is said that the U.S. can move to alternatives with an effort like the Manhattan Project.
A major feature of the Manhattan Project was the acquisition of uranium – the commodity necessary to make the whole thing work.
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.

A large scale move to renewable energy technologies is inconsistent with anti-mining advocacy.