Strategic & Critical Minerals – A Global Perspective

Energy Critical Elements – Securing Materials for Emerging Technologies

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University of Nevada, Reno
Statewide • Worldwide

* with help from Murray Hitzman, Colorado School of Mines

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Energy Critical Elements – Securing Materials for Emerging Technologies

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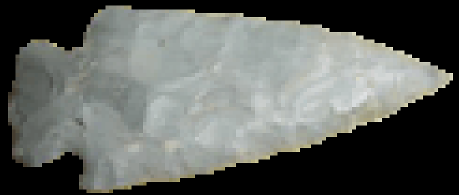
1. **Critical and strategic minerals will change with time.**
2. **Demand is high.**
3. **China will be a major force in the world of strategic and critical minerals.**
4. **The U.S.A. has the right geology to be a major force as well for many, but not all, minerals.**

Arrowhead clipart from www.firstpeople.us



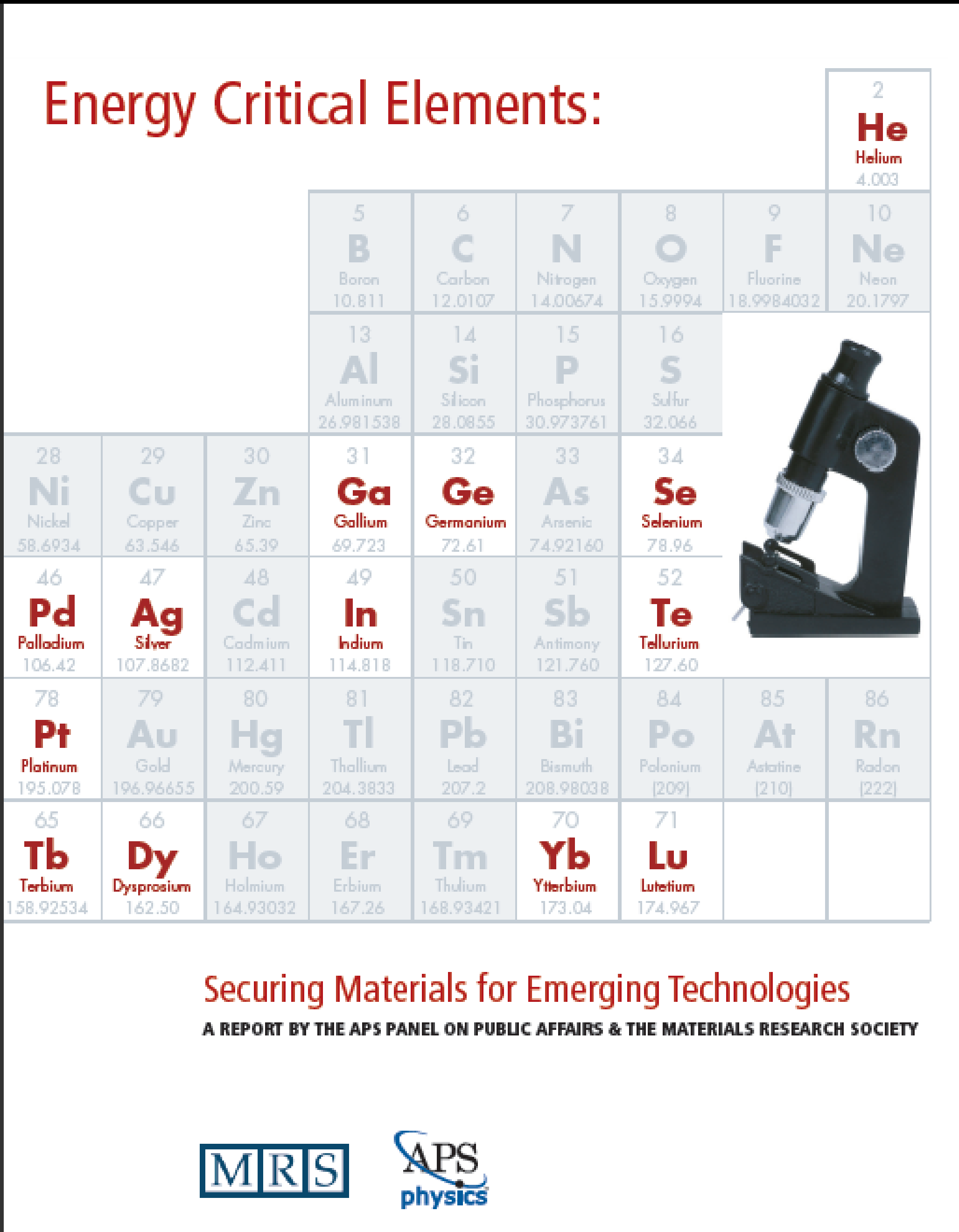
Critical and strategic minerals will change with time.

Avatar

Arrowhead clipart from www.firstpeople.us

Critical and strategic minerals will change with time.

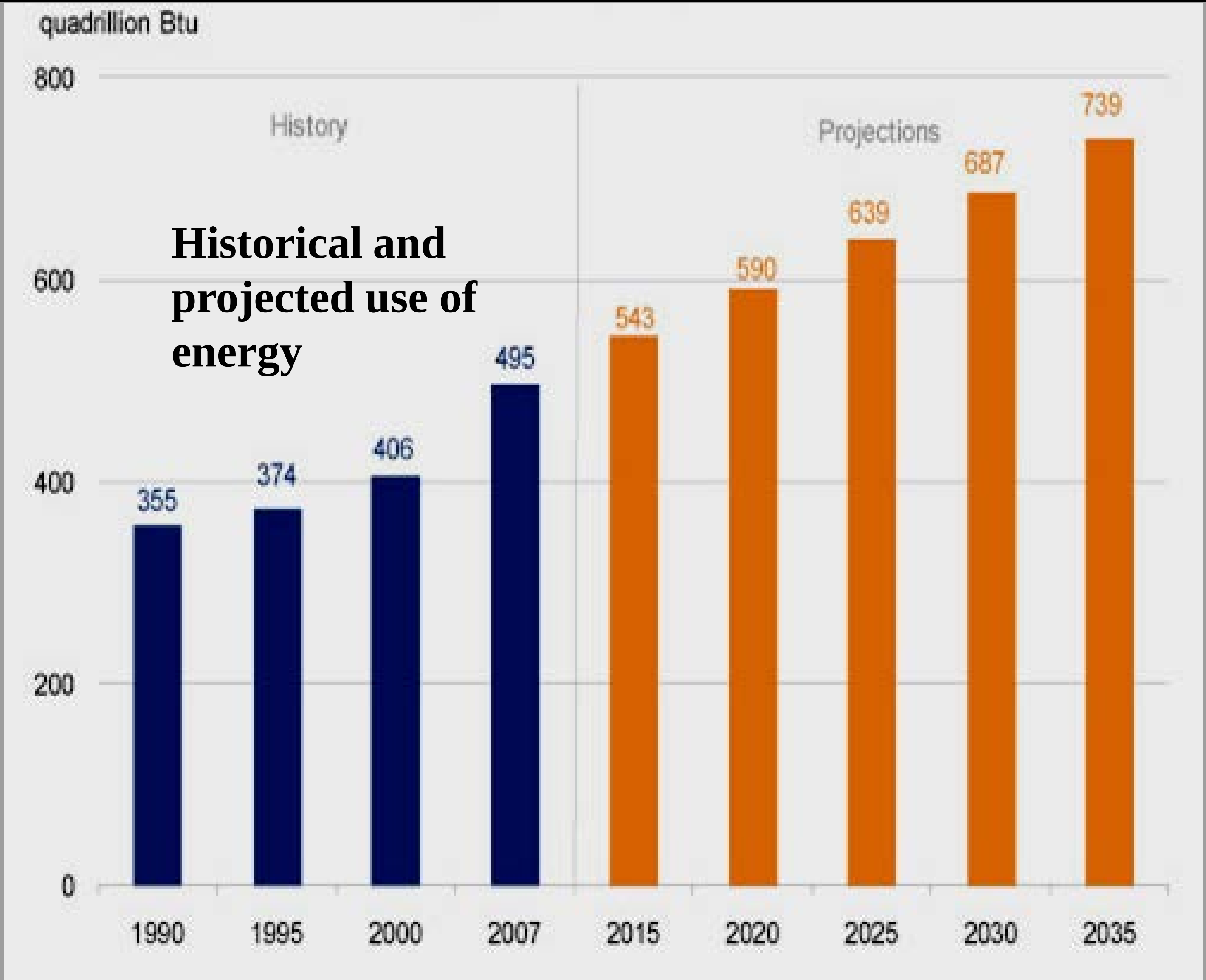
$CuIn_xGa_{(1-x)}Se_2$ or CIGS, for solar panels?
CdTe , GaAs, and Ge for solar panels?
Nd, Dy for magnets for wind and other electrical turbines?
Li and V for different types of batteries?



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.

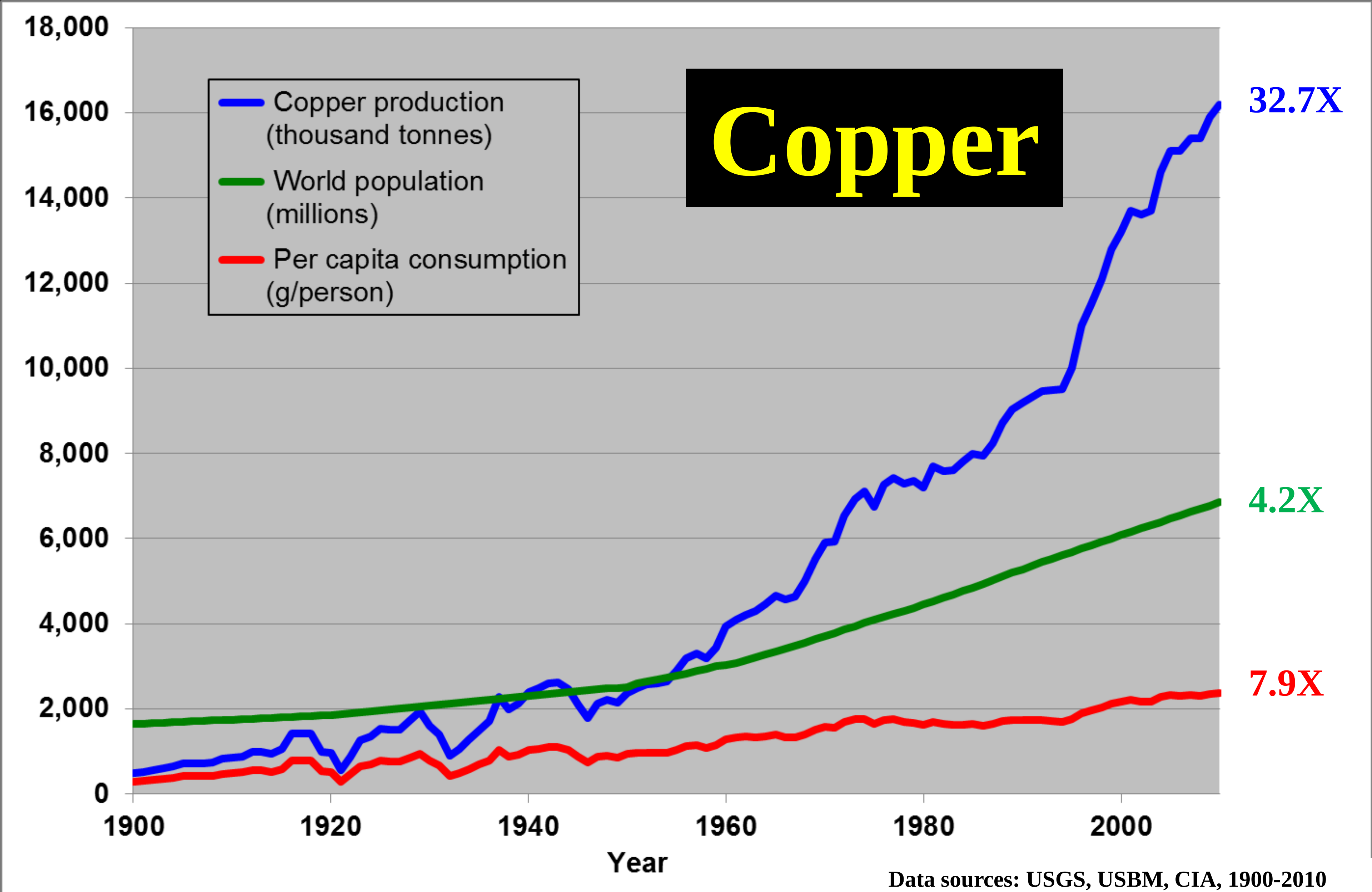
Robert Jaffe, MIT, Chair
Jon Price, NBMG, Co-Chair

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.

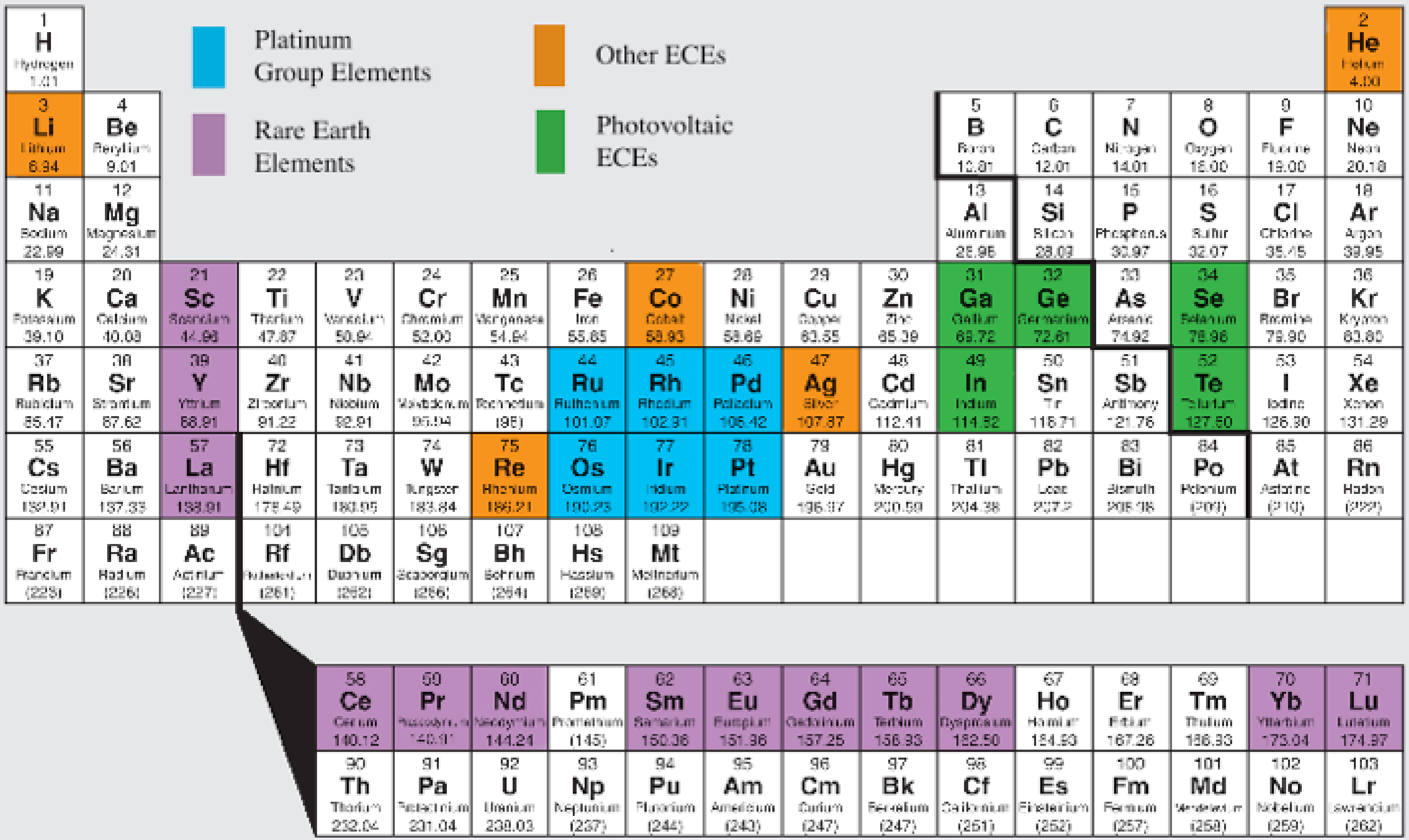
Photo copyrighted by Michael Collier, from the AGI website, Rio Tinto/Kennecott Utah Copper mine; the remaining resource as of 16 May 2008 = 3.06 million metric tons of Cu

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

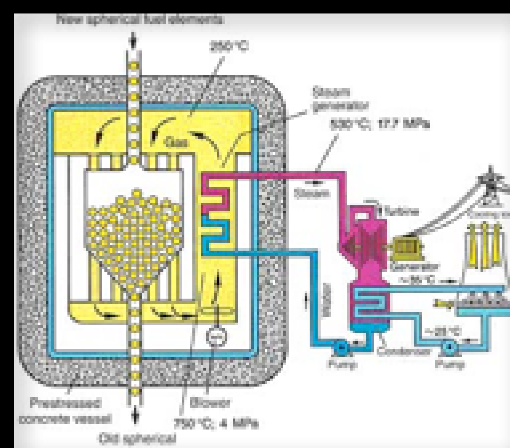
- **Renewable**
- **CO_2 neutral**

Tellurium Gallium
Indium Germanium

Neodymium
Dysprosium
Praseodymium
Samarium

Terbium

Europium

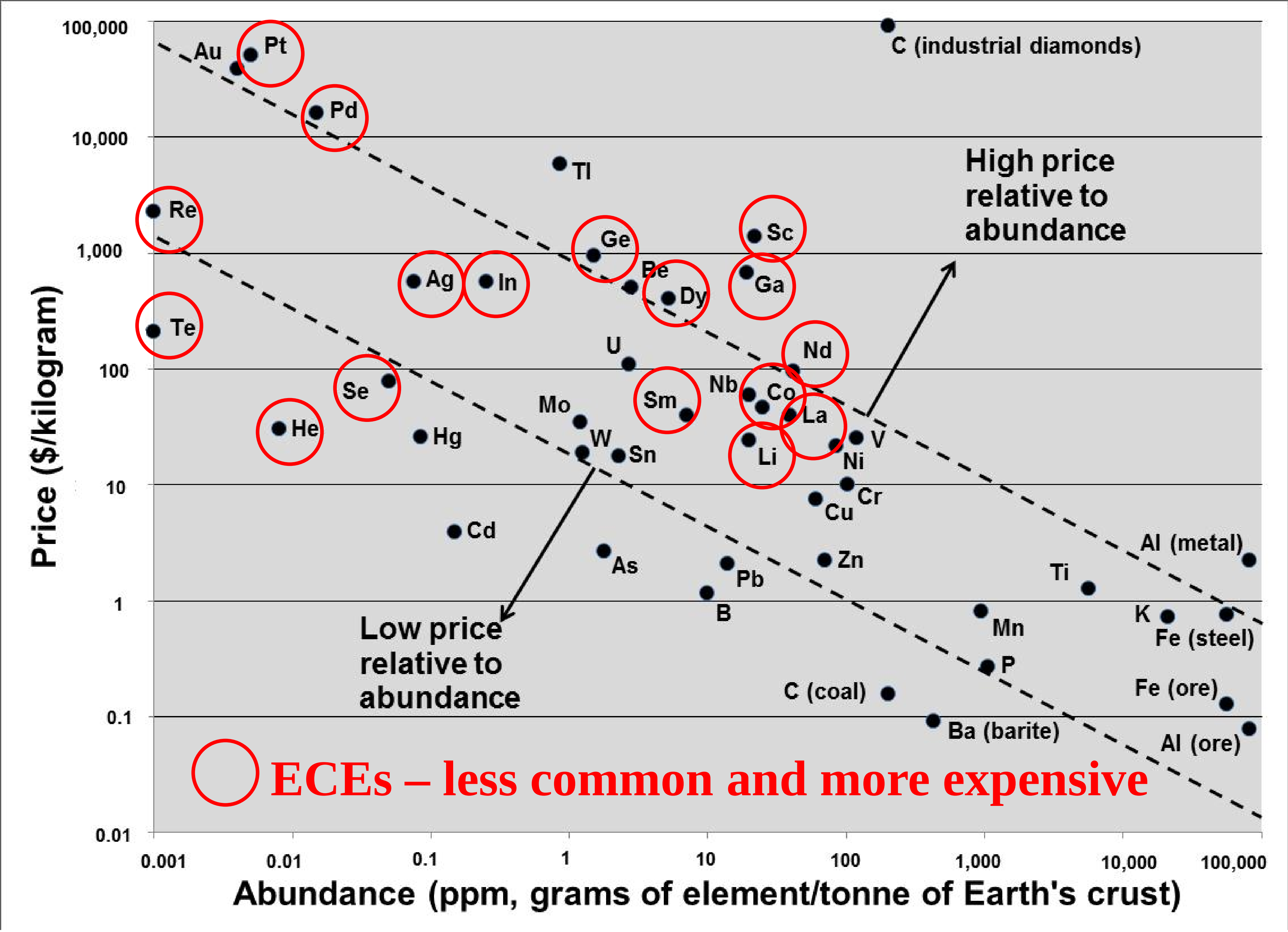


Helium

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



Source of data: USGS, EIA, CRC Handbook of Chemistry and Physics, others

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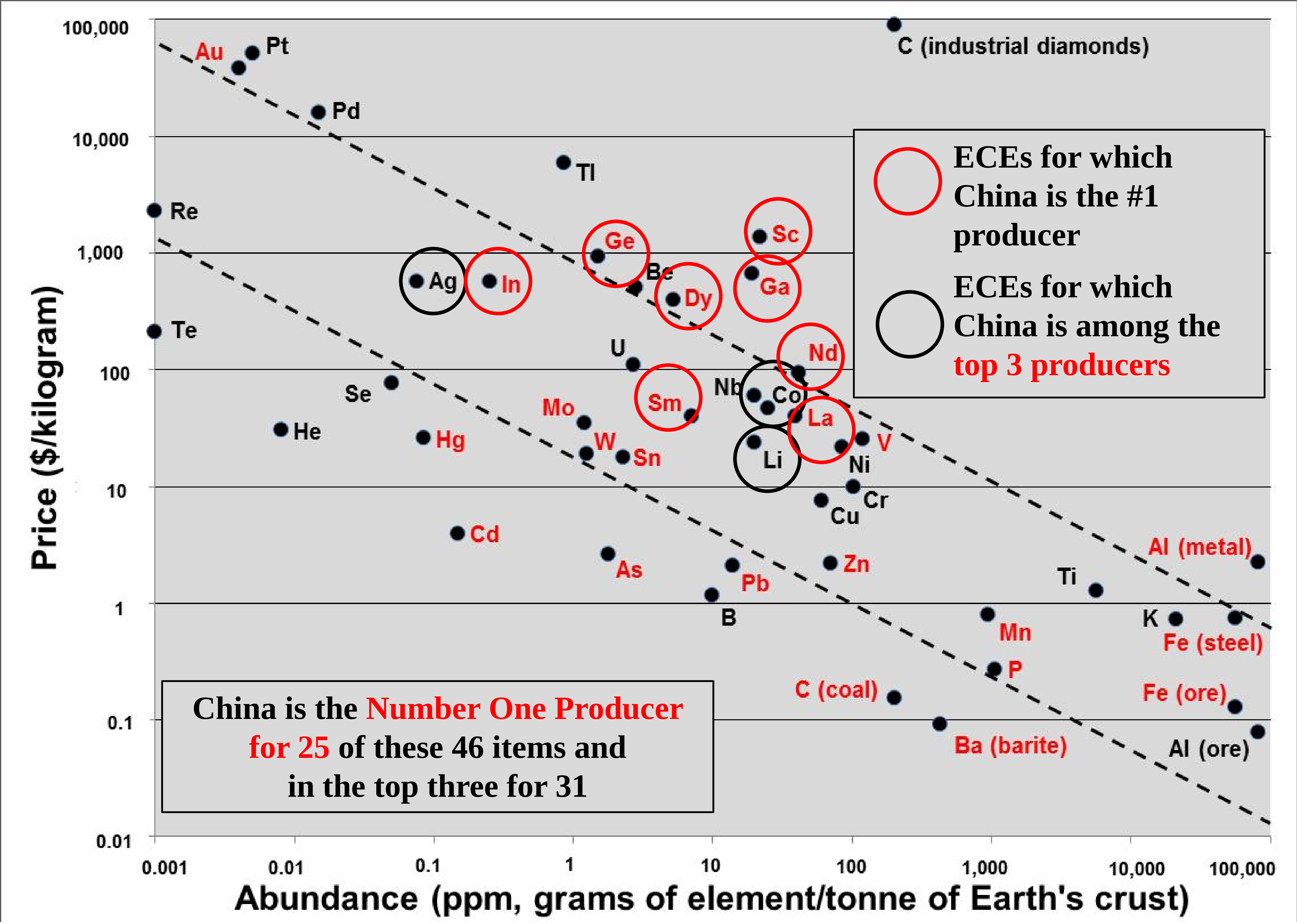

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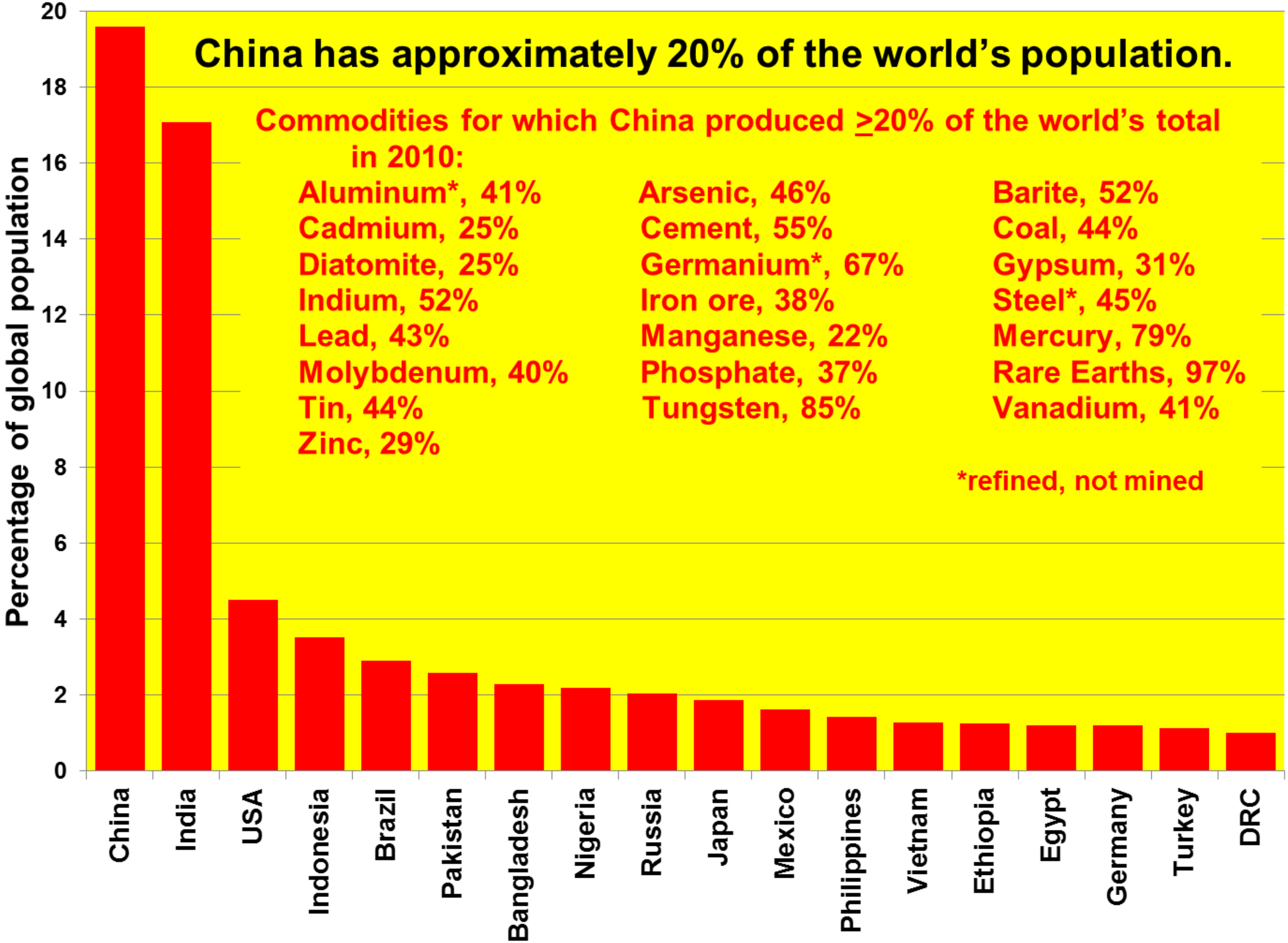
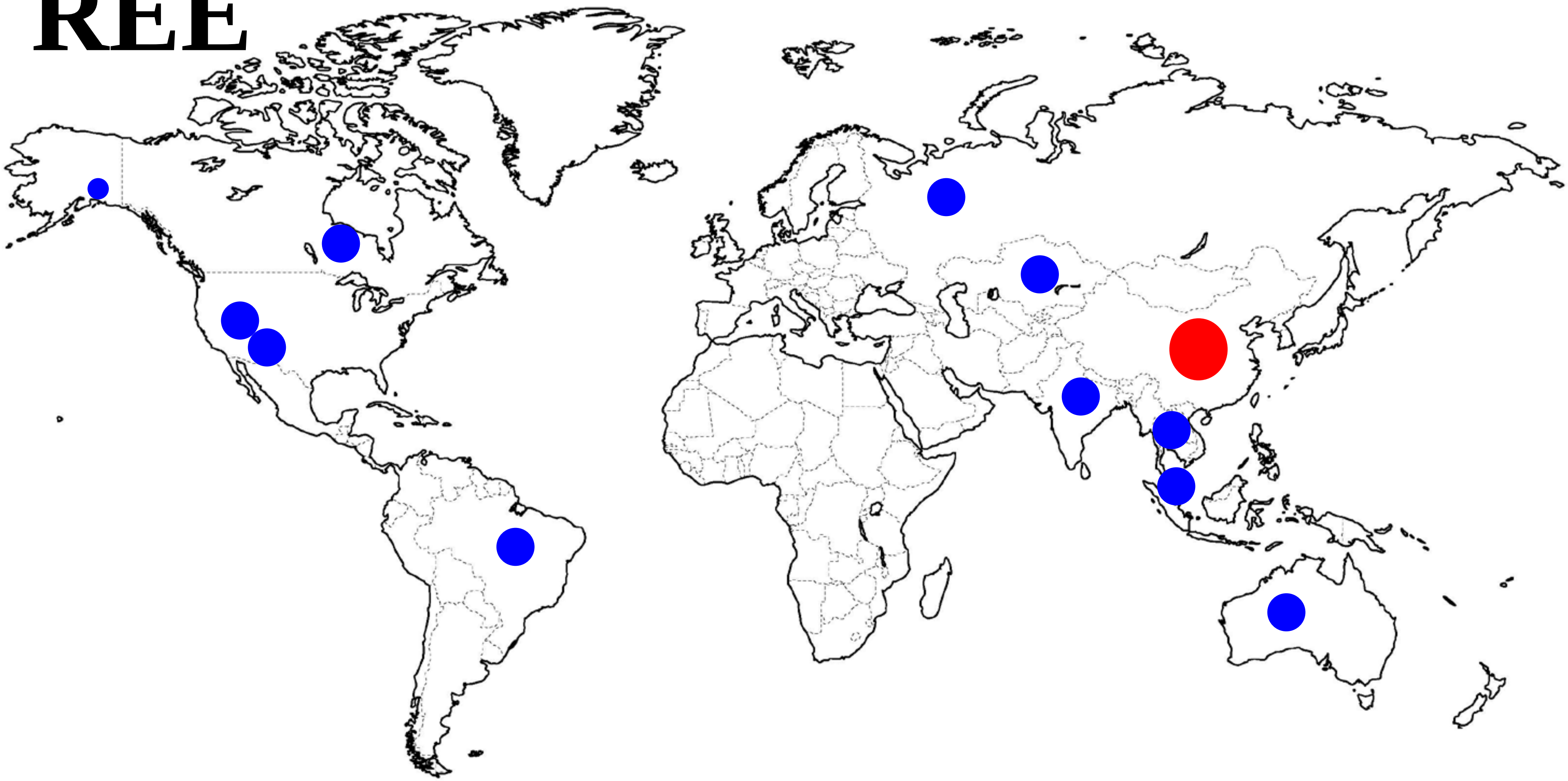


Data sources: USGS, EIA, CIA

REE

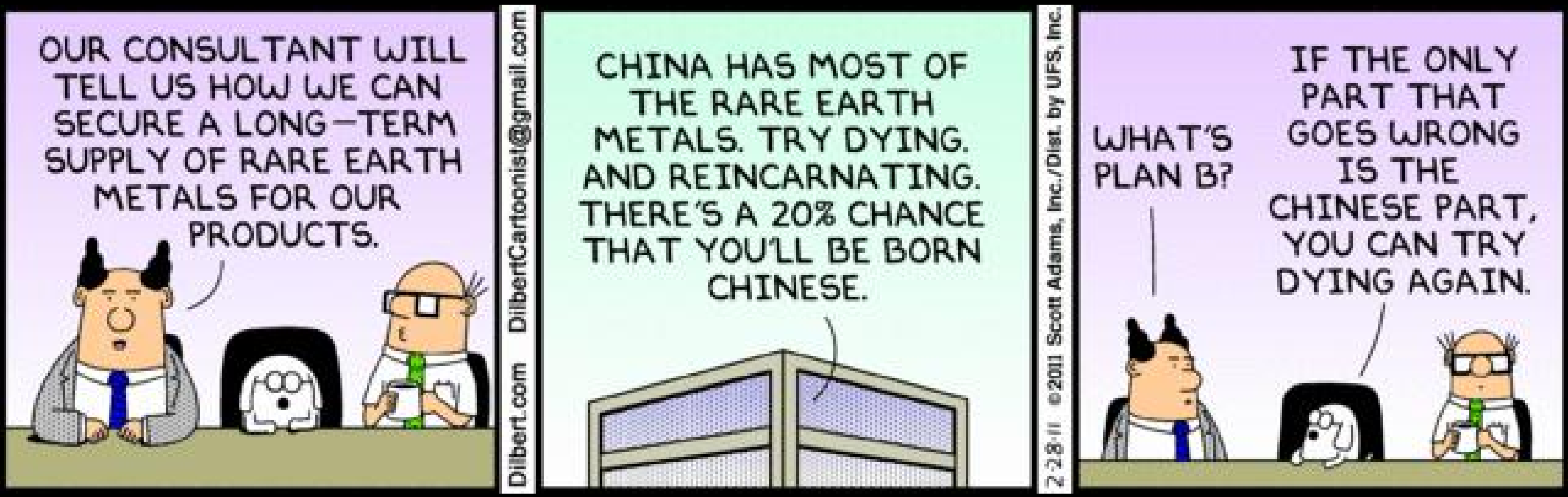


World's leading rare earth producer (China, 97%)

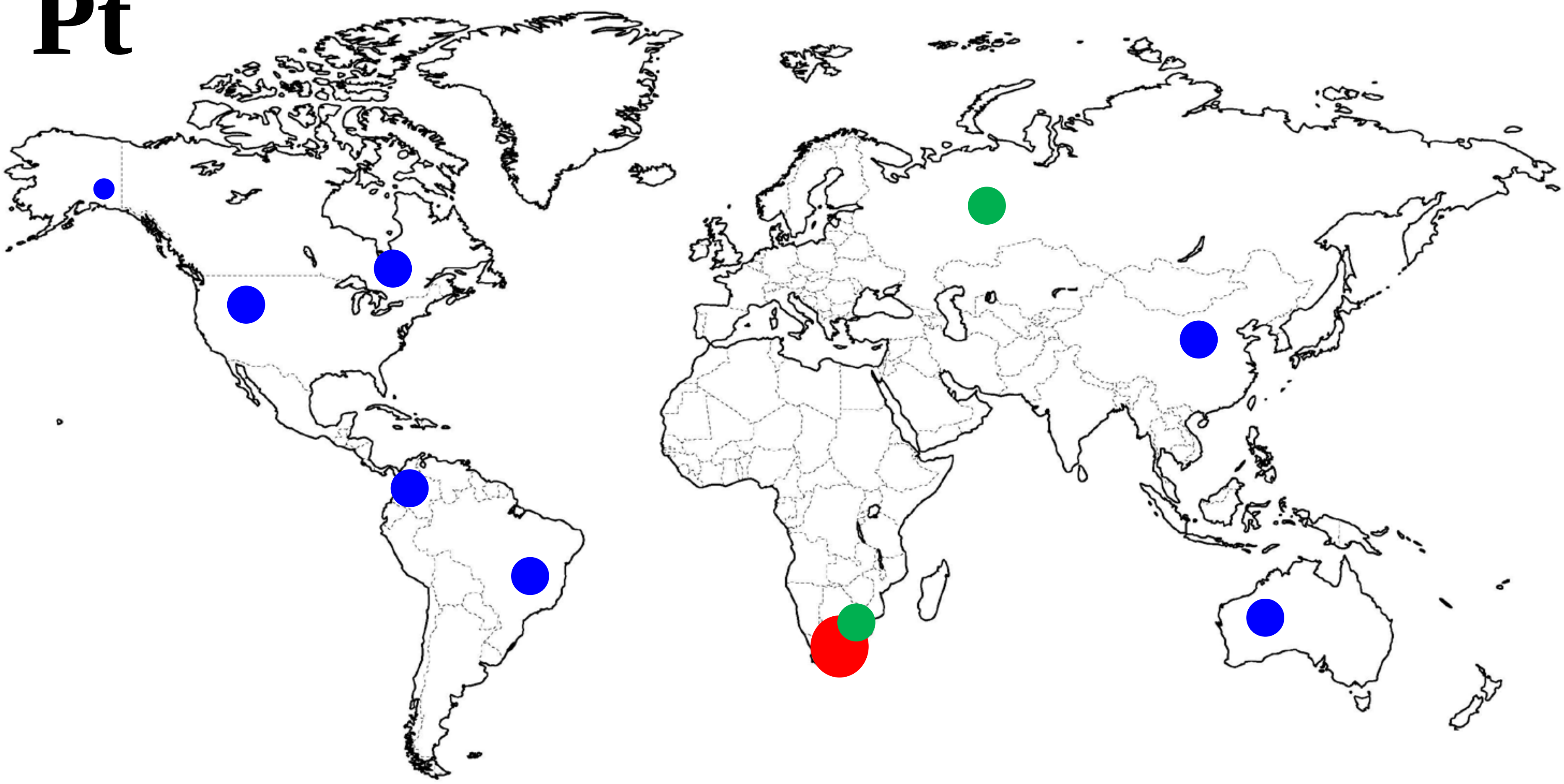
Countries with 4% or more of global production - none

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.
Dilbert.com DilbertCartoonist@gmail.com
CHINA HAS MOST OF THE RARE EARTH METALS. TRY DYING. AND REINCARNATING. THERE'S A 20% CHANCE THAT YOU'LL BE BORN CHINESE.
2-28-11 ©2011 Scott Adams, Inc./Dist. by UFS, Inc.
WHAT'S PLAN B?
IF THE ONLY PART THAT GOES WRONG IS THE CHINESE PART, YOU CAN TRY DYING AGAIN.

Pt



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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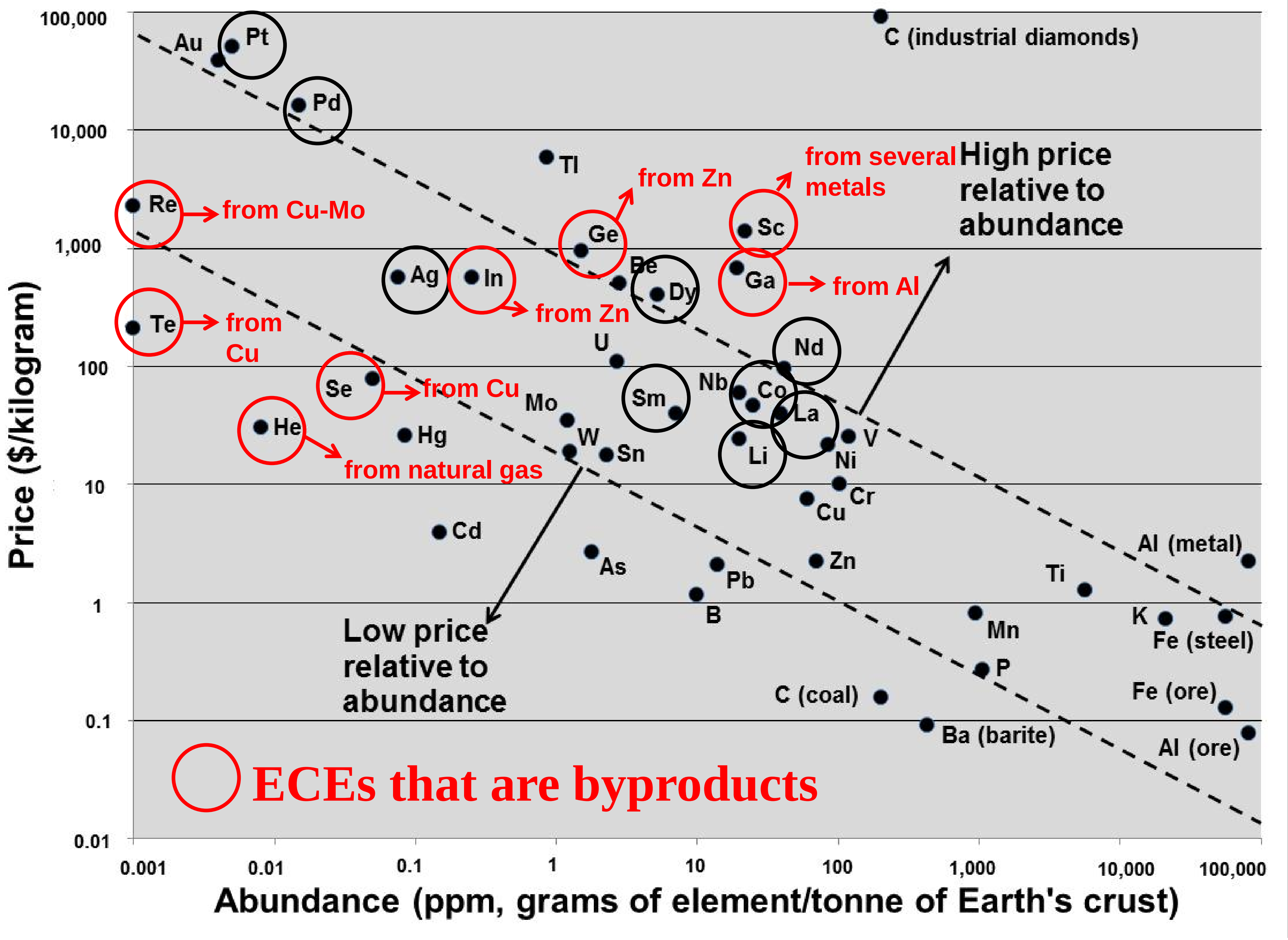

Source of data: USGS, EIA, CRC Handbook of Chemistry and Physics, others

	Main product Cu	Byproduct Se	Byproduct Te
Global production (metric tons)	**16,200,000**	**2,260**	**~500**
Price ($/kg)	**$7.54/kg**	**$77.16/kg**	**$210/kg**
Value of global production ($)	**$122 x 10^9**	**$174 x 10^6**	**$105 x 10^6**
Ratio of values of global production		**Cu:Se = 700:1**	**Cu:Te = 1200:1**

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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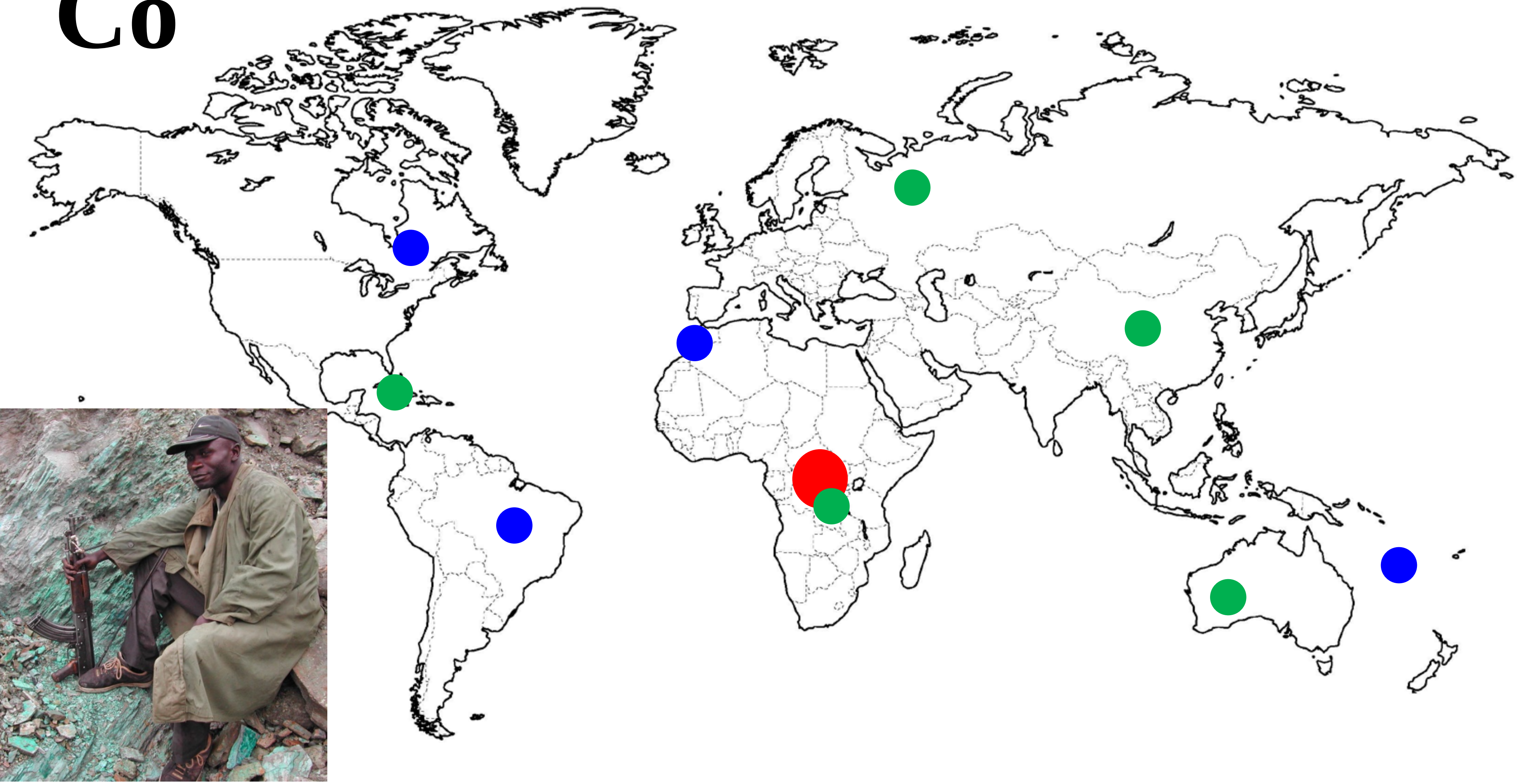
Collapsed shaft in the street by the school in Virginia City, Nevada (circa 1995, from mining in the late 1800s) – The principal's car went into the "sinkhole."

Co



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."

Energy Critical Elements – Securing Materials for Emerging Technologies

Thank you!

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

Year	Quota
2005	65,609 t REO*
2006	61,821 t REO
2007	59,643 t REO
2008	56,643 t REO
2009	50,145 t REO
2010	30,258 t REO
(first half 2011)	14,508 t REO

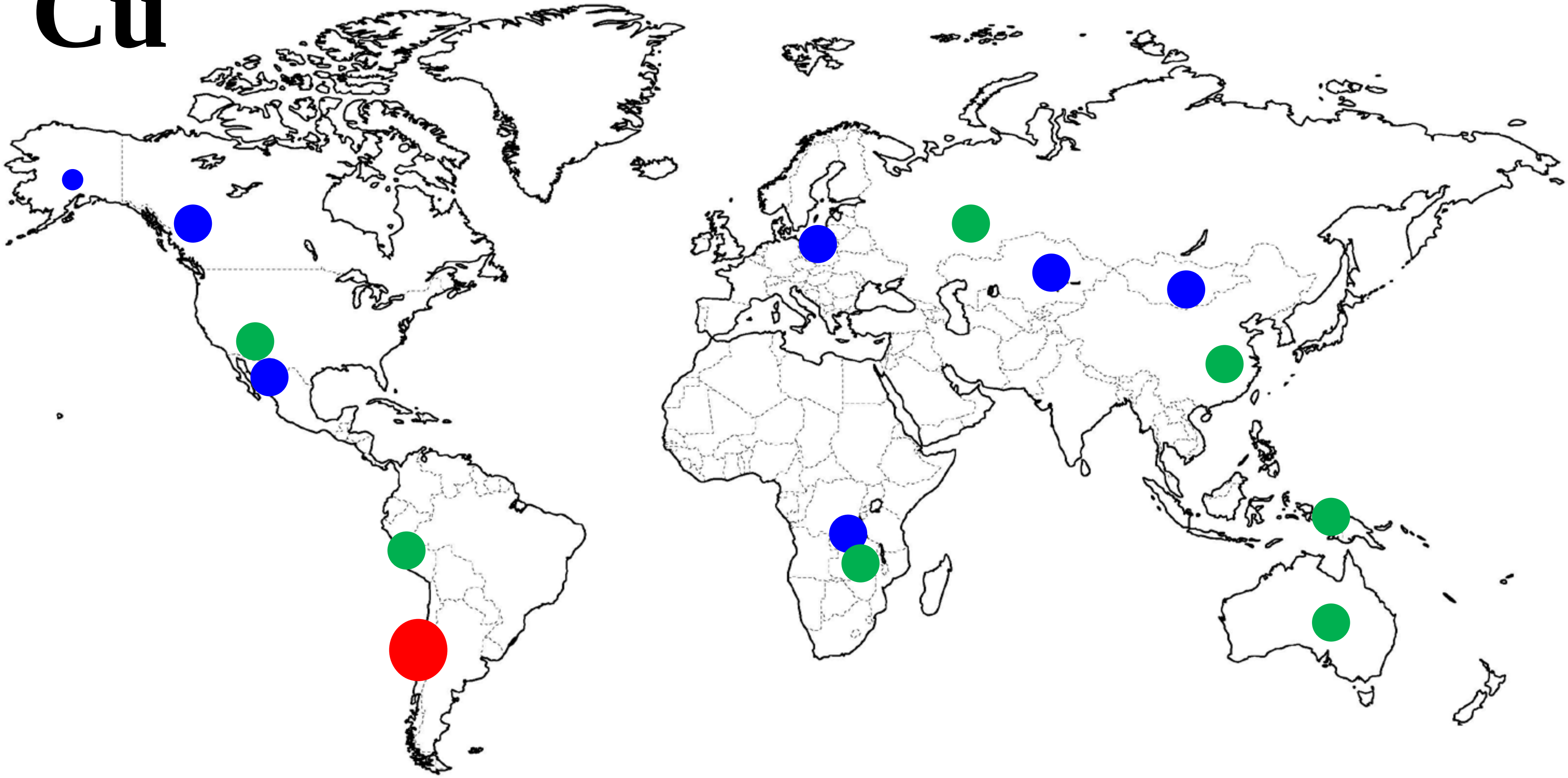
*** REO = rare earth oxides**

- **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.

Cu



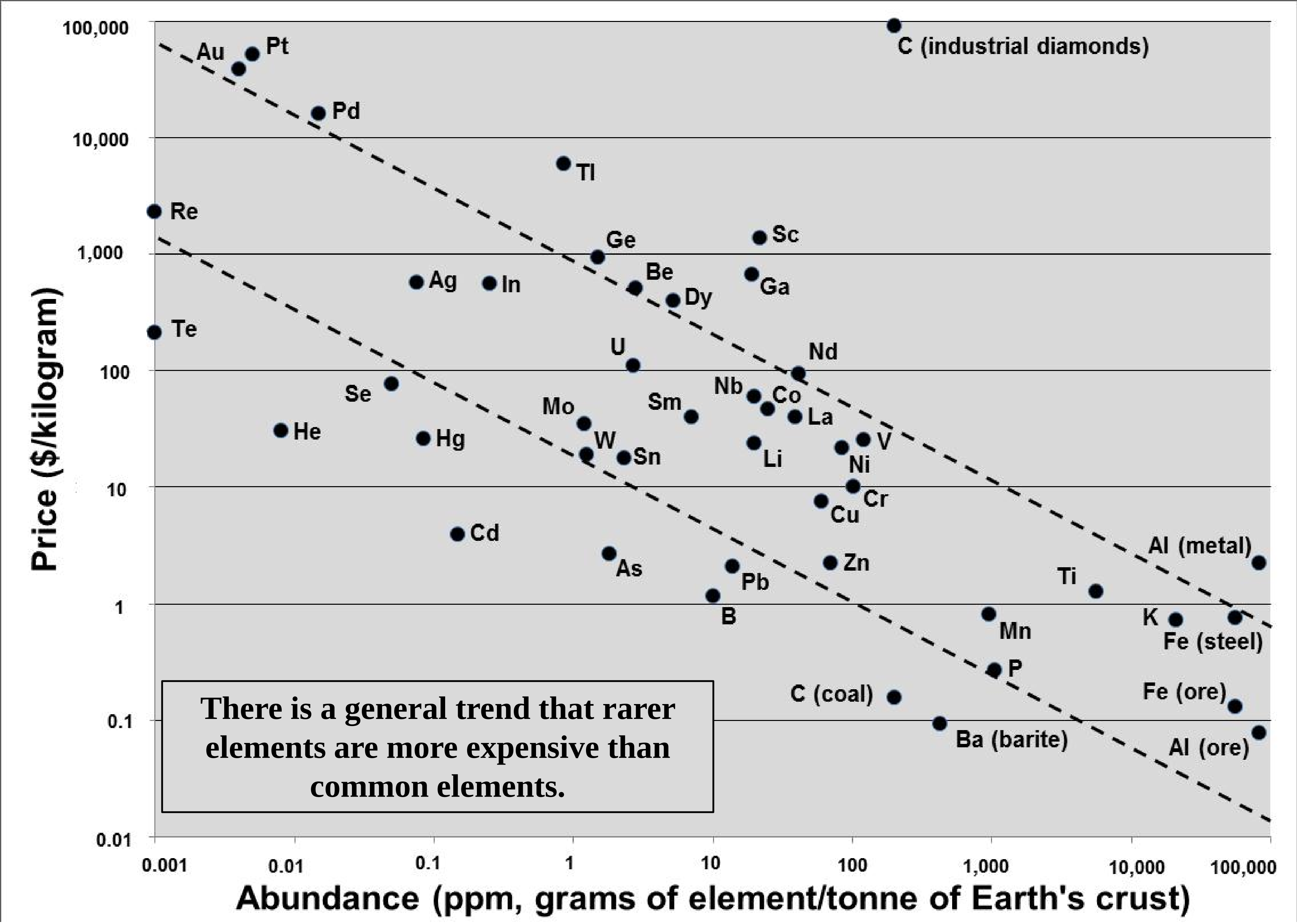
World's leading copper producer (Chile, 34%)

Countries with 4% or more of global production

Other countries with production or major reserves

Copper resources are broadly distributed.

Data source: USGS



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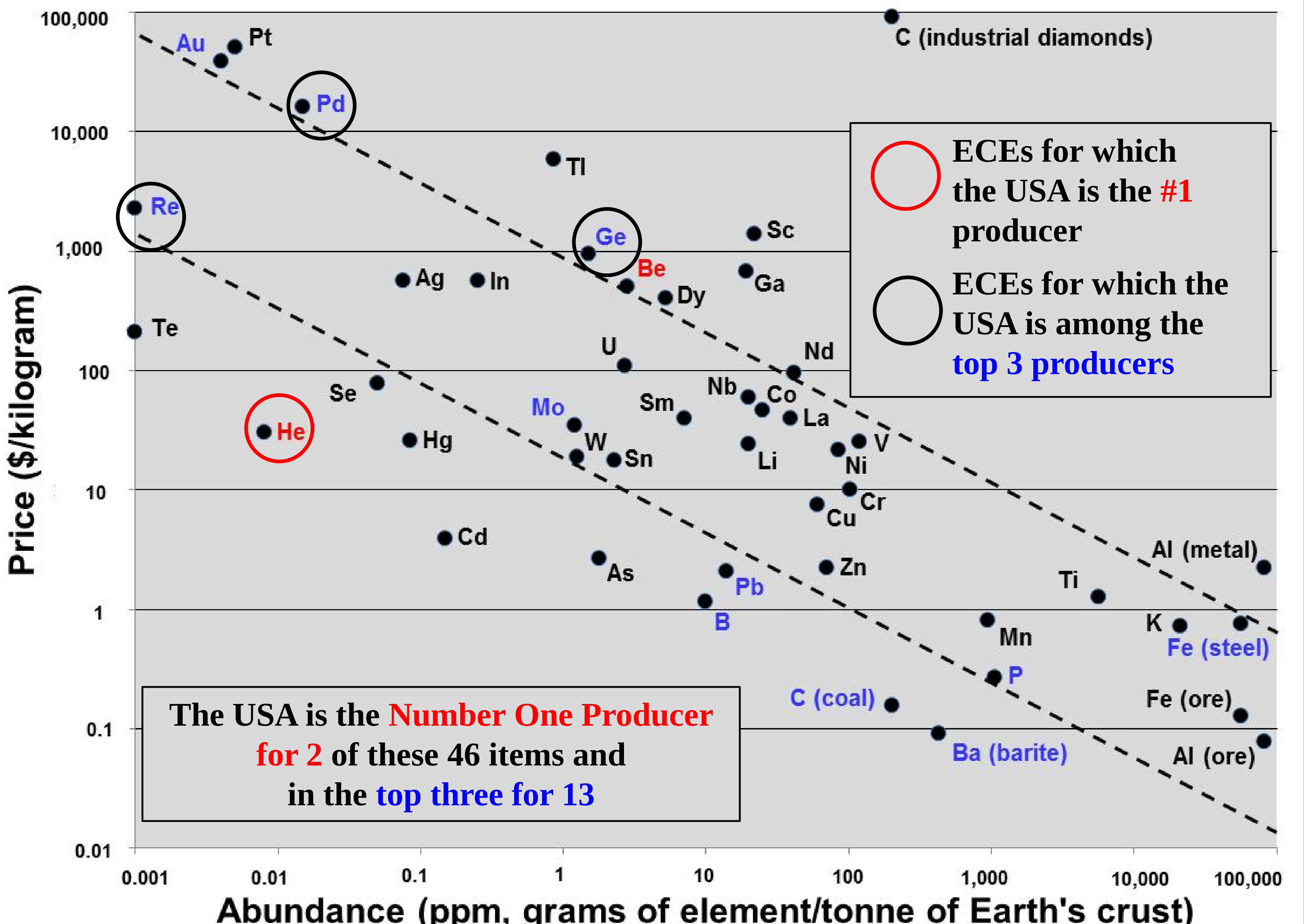

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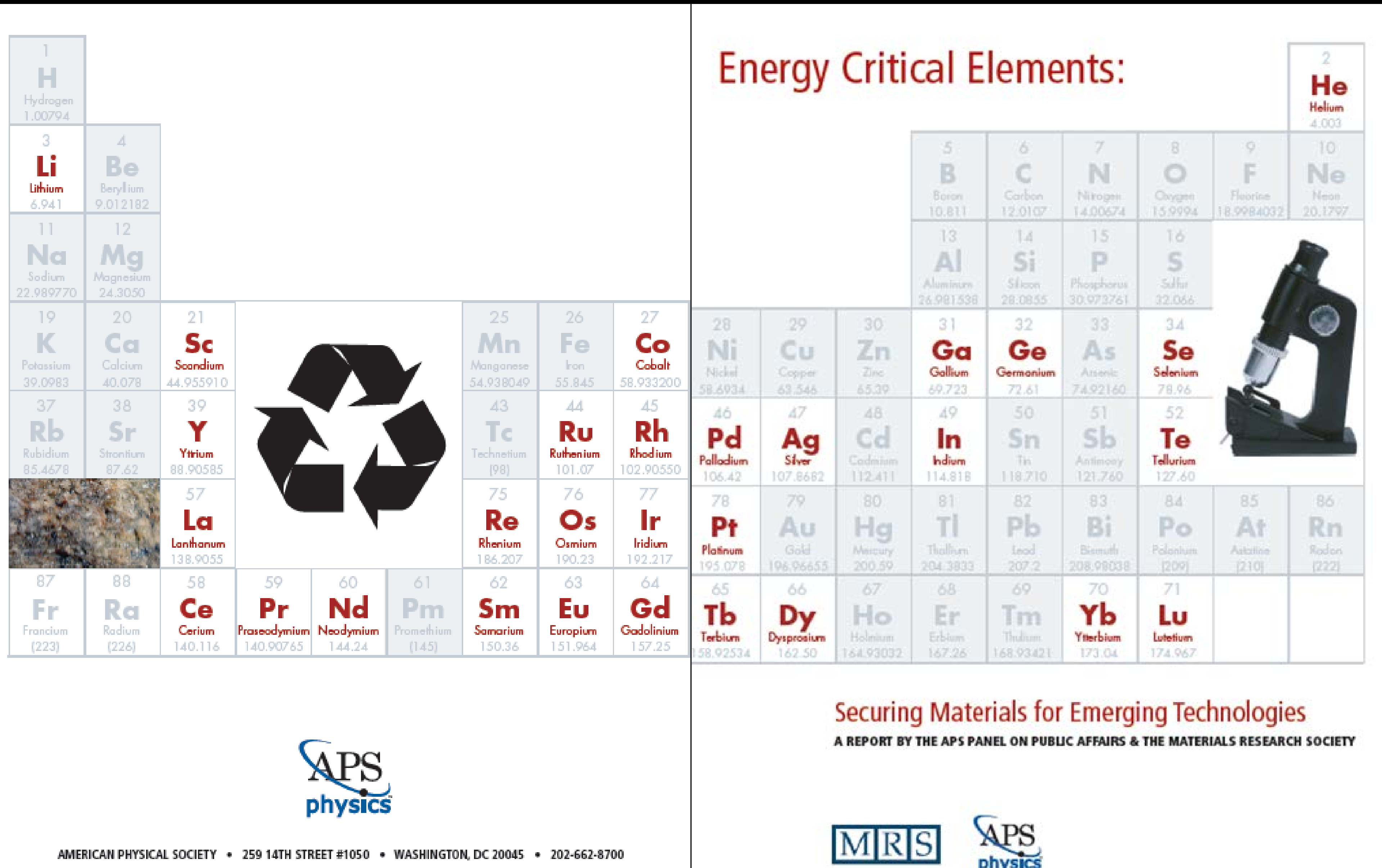
This report surveys potential constraints on the availability of ECEs and then identifies **five specific areas of potential action** by the United States to insure their availability:

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
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