

Energy and mineral supply chains and the circular economy

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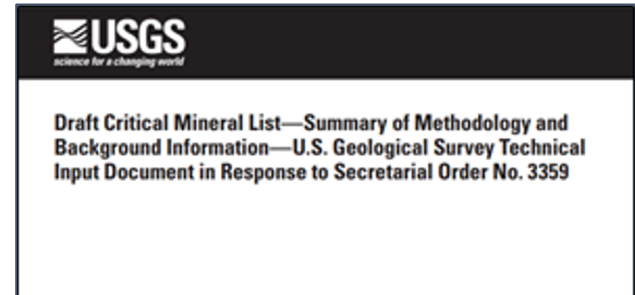
Federal strategy on critical mineral supply chains

National Science & Technology Council – Critical Minerals Subcommittee (2011–)

- Definitions of criticality, for multiple sectors

Executive Order 13817 (2017)

- List of Critical Minerals (2018)
- Interagency Federal strategy on critical minerals (2019)
 1. Advance Transformational R&D Across Critical Mineral Supply Chains
 2. Strengthen America’s Critical Mineral Supply Chains and Defense Industrial Base
 3. Enhance International Trade and Cooperation Related to Critical Minerals
 4. Improve Understanding of Domestic Critical Mineral Resources
 5. Improve Access to Domestic Critical Mineral Resources on Federal Lands and Reduce Federal Permitting Timeframes
 6. Grow the American Critical Minerals Workforce



Mineral commodities are essential to energy applications

Renewable energy

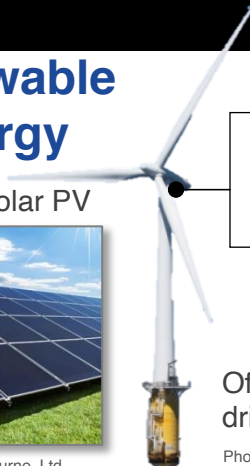
49
In
Indium

31
Ga
Gallium

34
Se
Selenium



Photo credit: Testbourne, Ltd.



Offshore direct drive wind turbine

Photo credit: US DOE

60
Nd
Neodymium

66
Dy
Dysprosium

Oil drilling and refining

56
Ba
Barium



78
Pt
Platinum

75
Re
Rhenium

Gas turbines

13
Al
Aluminum

24
Cr
Chromium

27
Co
Cobalt

28
Ni
Nickel

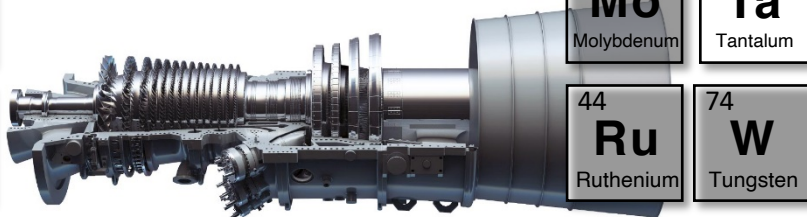


Photo credit: General Electric

42
Mo
Molybdenum

44
Ru
Ruthenium

72
Hf
Hafnium

73
Ta
Tantalum

74
W
Tungsten

75
Re
Rhenium

Electric vehicles and energy storage

3
Li
Lithium

27
Co
Cobalt

25
Mn
Manganese

6
C
Carbon

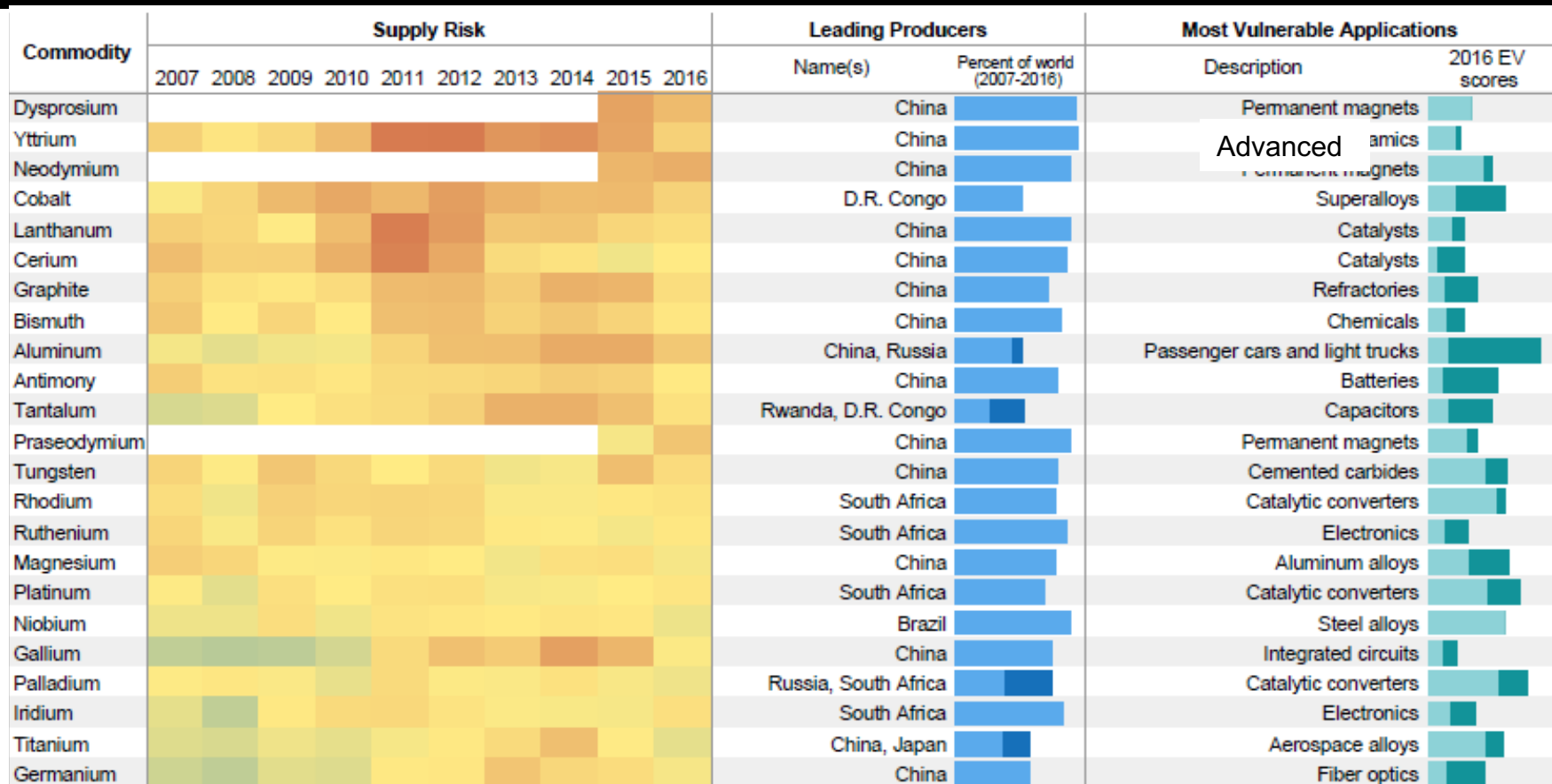
28
Ni
Nickel



Photo credit: Telsa, Inc.

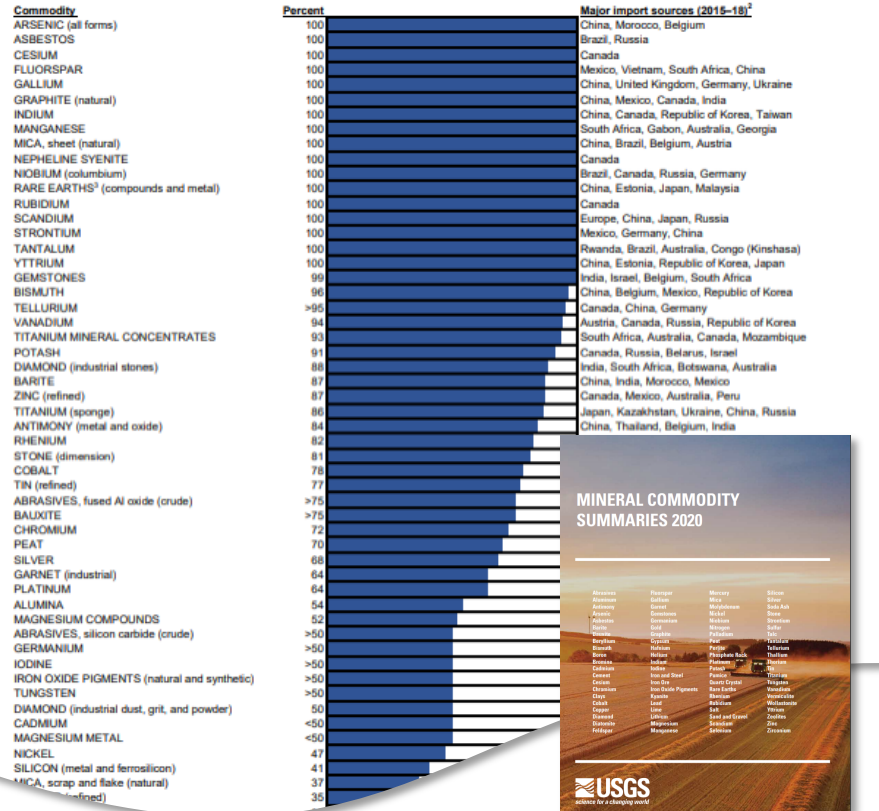
Electric and hybrid vehicles

Commodity supply risks to the U.S. manufacturing sector

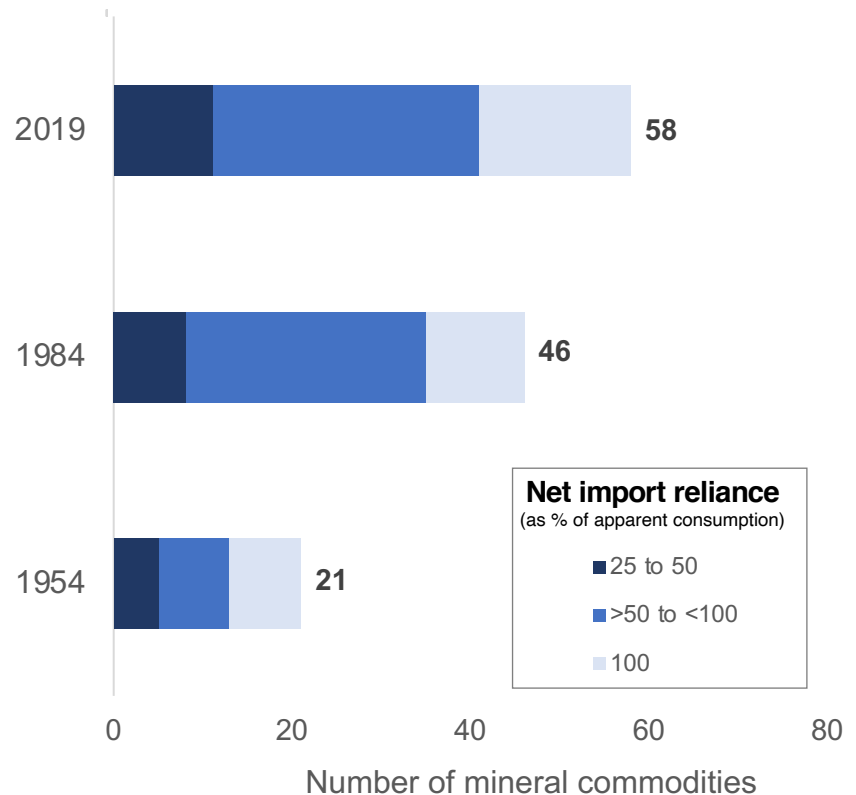


United States reliance on imports is growing

2019 U.S. net import reliance



Growing U.S. net import reliance

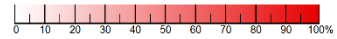
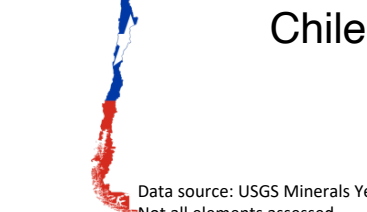
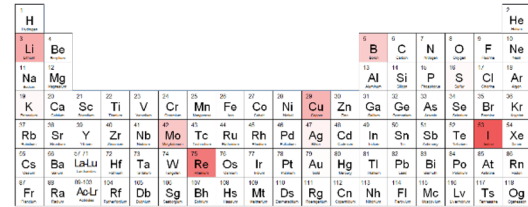
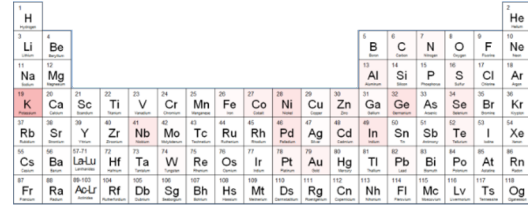
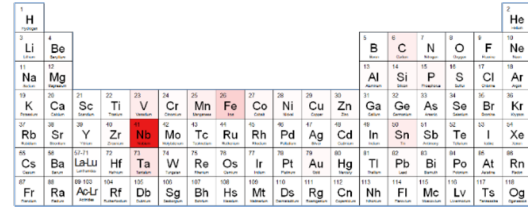
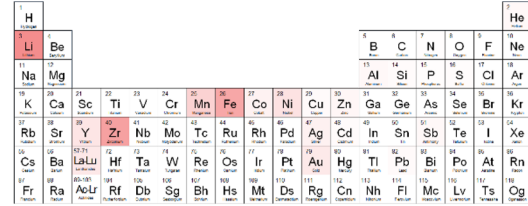
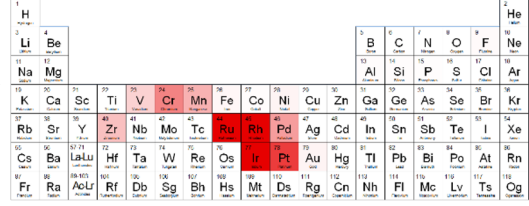
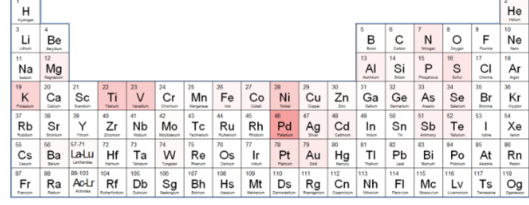
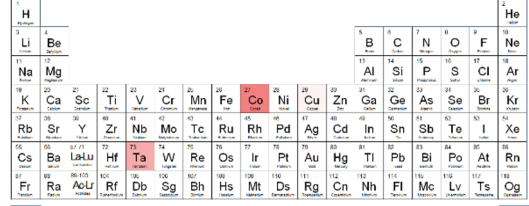
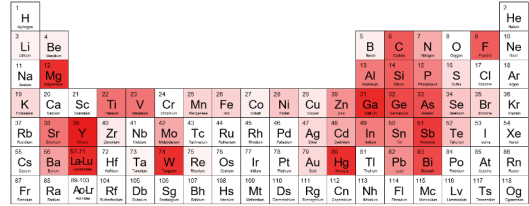
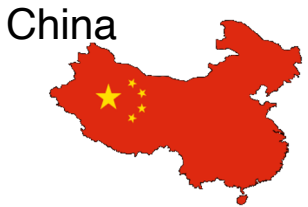


U.S. Geological Survey, 2020, Mineral Commodity Summaries 2020
 Fortier et al., 2015, Comparison of U.S. net import reliance for nonfuel mineral commodities—A 60-year retrospective (1954–1984–2014): U.S. Geological Survey

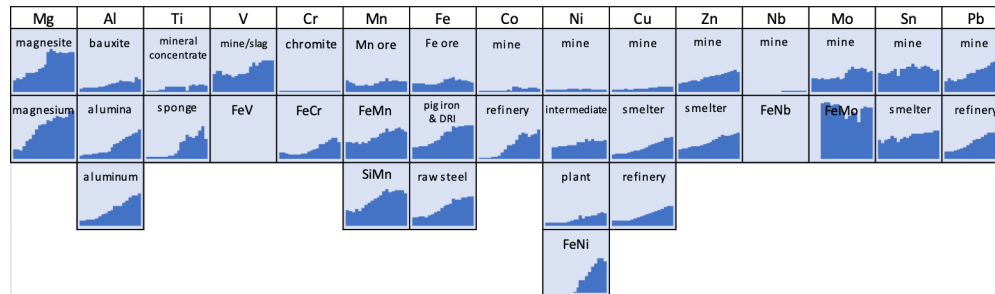
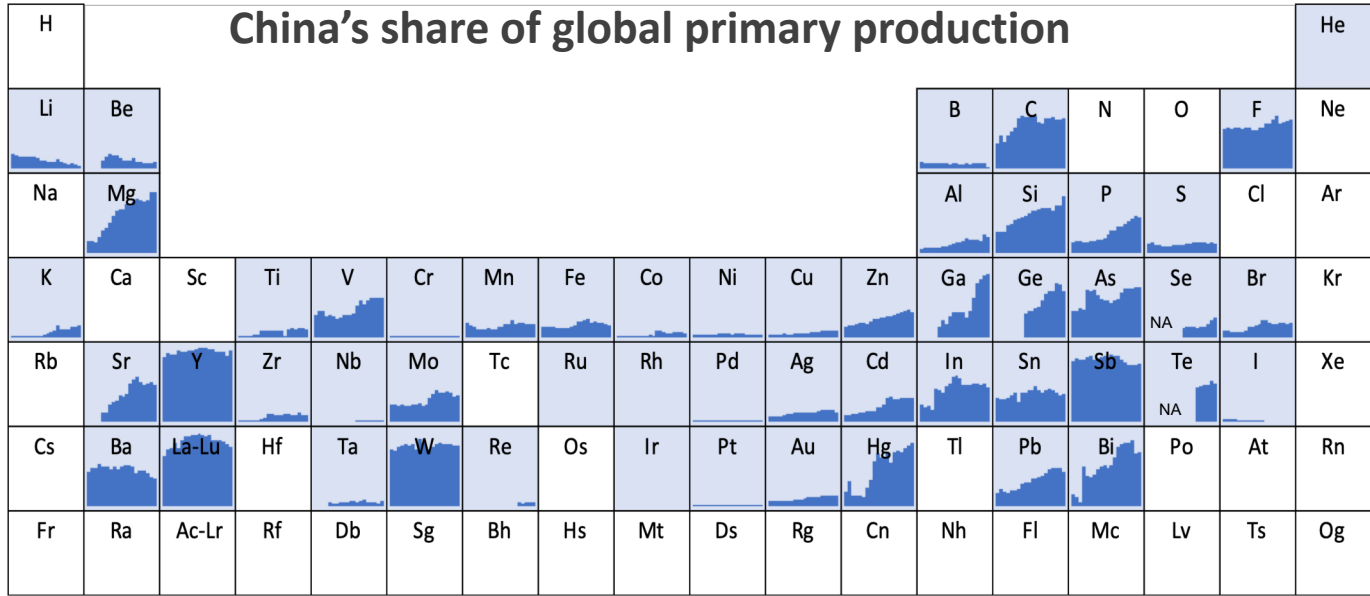


Production of many minerals is highly concentrated

Share of each element's global production from selected countries



Global production trends over 20 years



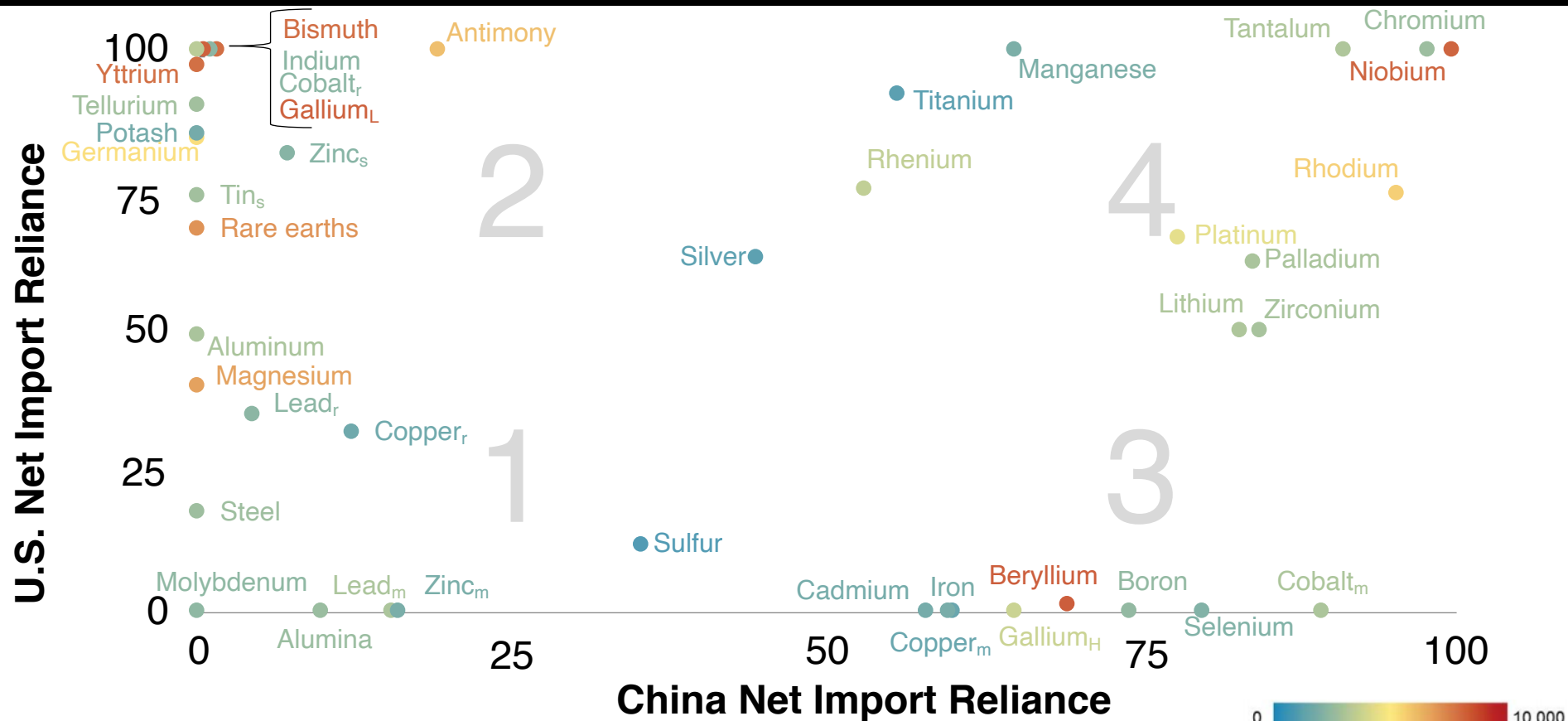
EXPLANATION

Element symbol

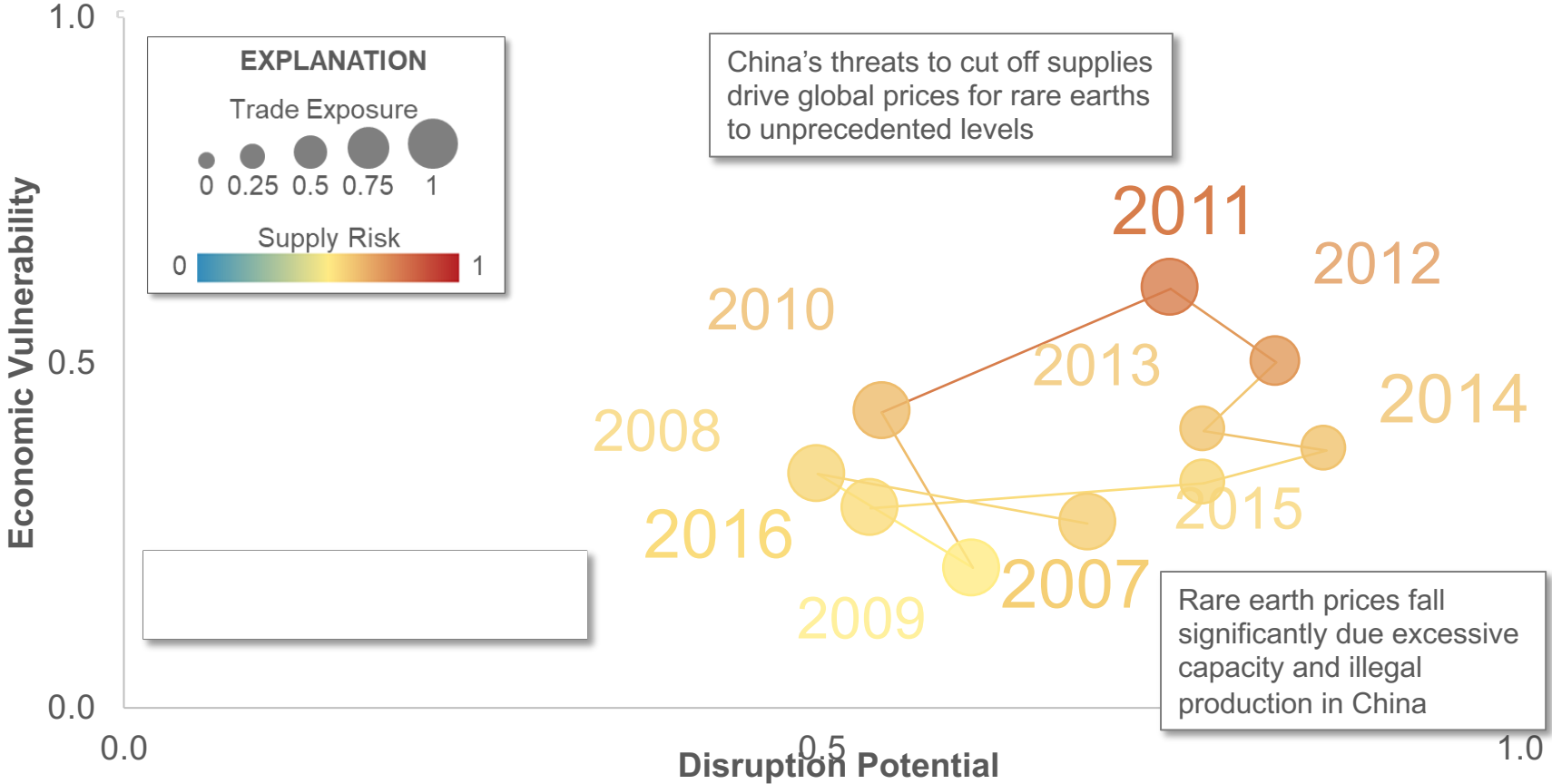
China's share of global primary production (0-100%)

Time series (1996-2015)

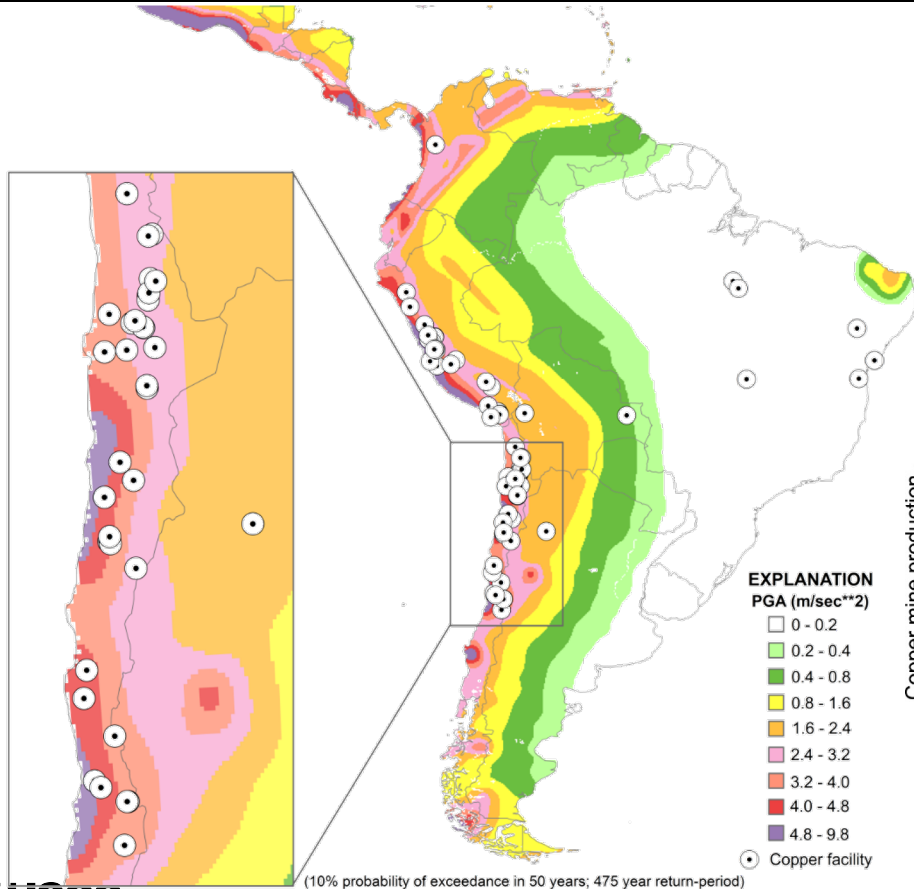
Import reliance can highlight interdependencies and competition potential



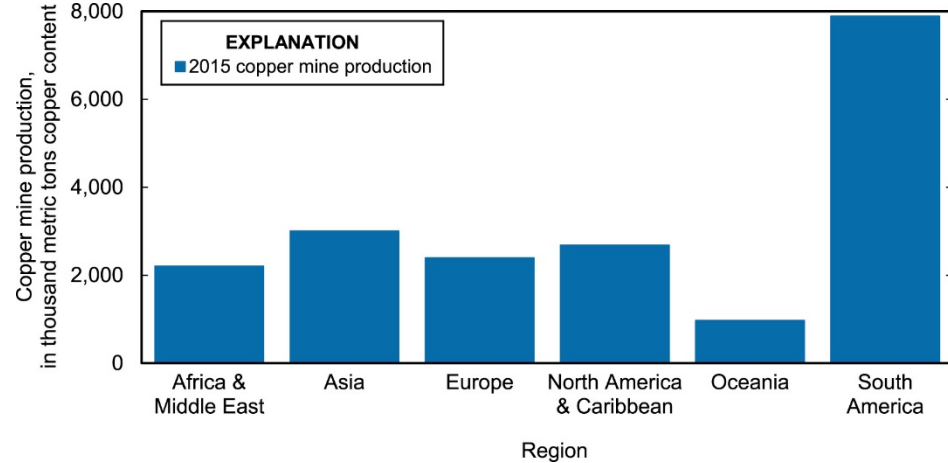
Trends in trade exposure: Lanthanum



Additional causes of supply chain disruption: Natural hazards

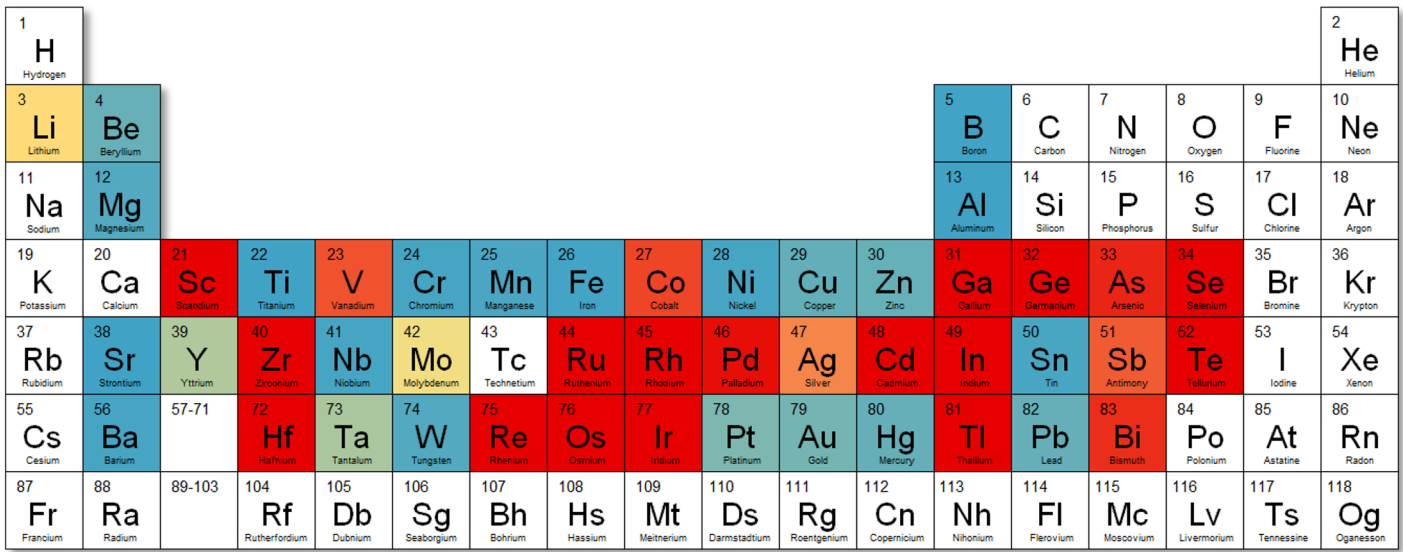


Spatial concentration of mineral production in tectonically active areas may pose a higher risk of supply disruption

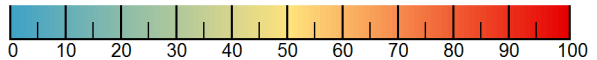


Many byproduct minerals are required for advanced technologies

Share of element's primary production obtained as a byproduct



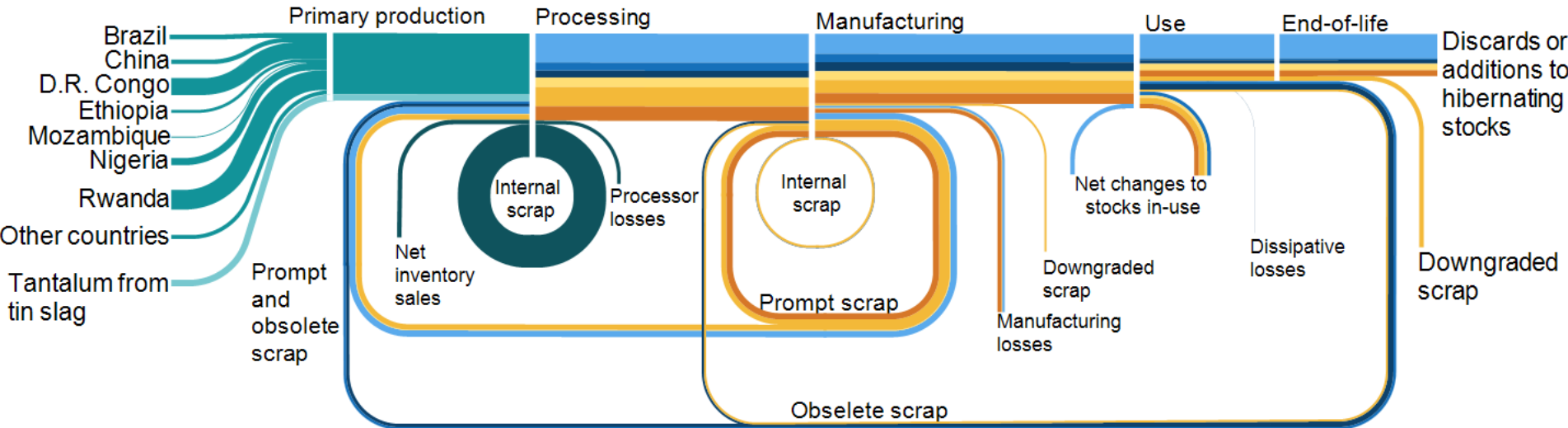
Lanthanide series	57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
Actinide series	89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium



Tracking mineral commodities throughout their life cycle

Global flows of tantalum

(metric tons of Ta content, circa 2015)



Summary

- Federal strategy
- Potential futures
- Sectoral dependencies
- Foreign supply dependencies
- Domestic supply dependencies
- Potential for unconventional resources