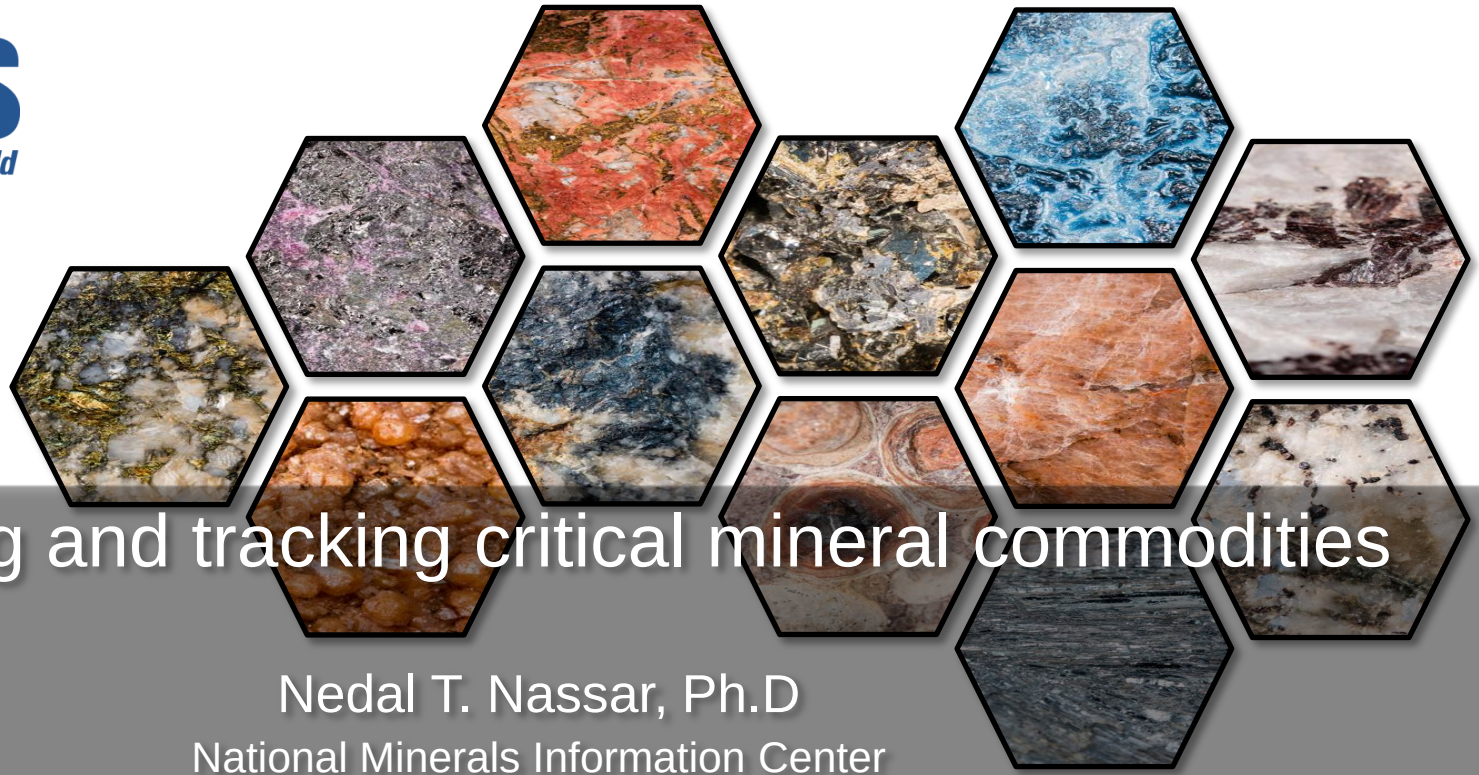

Assessing and tracking critical mineral commodities

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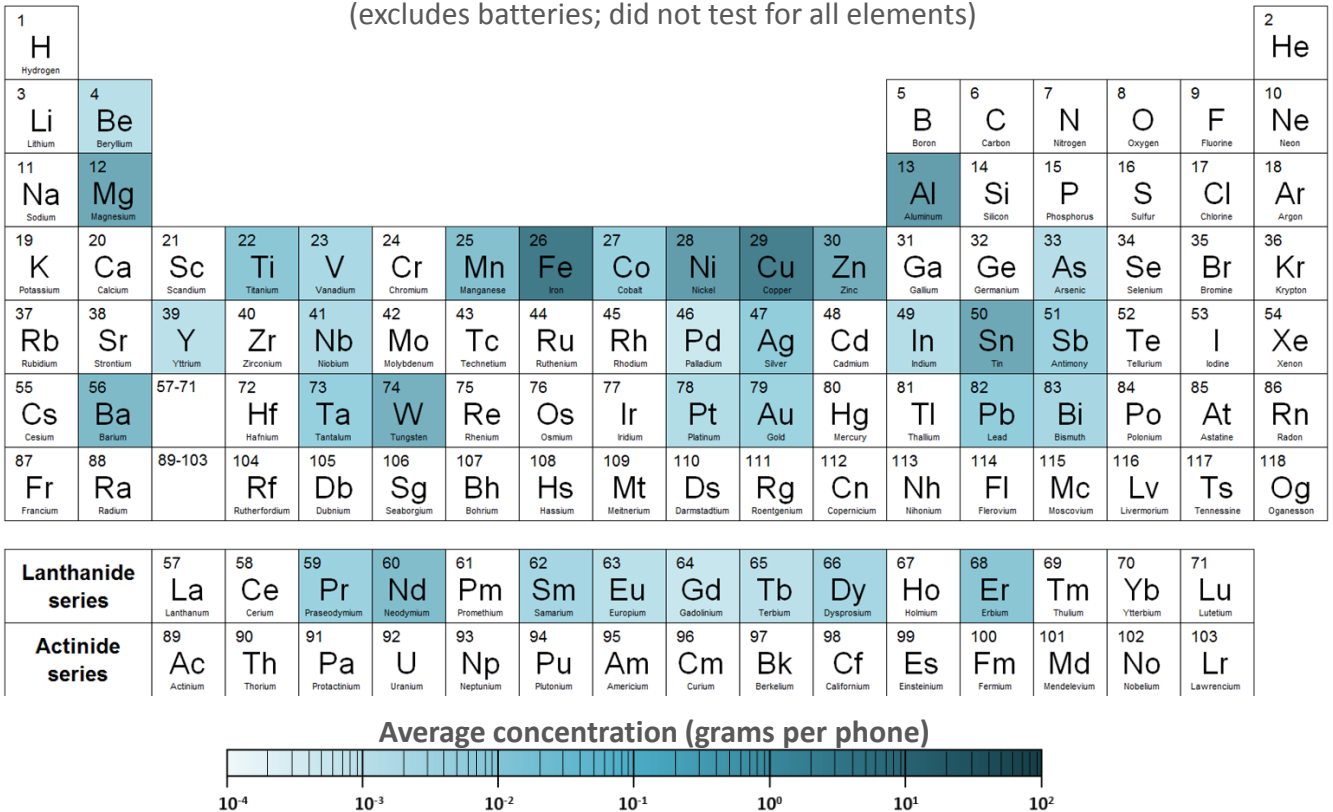
National Minerals Information Center
U.S. Geological Survey

January 26, 2018

Modern technology makes use of a wide range of elements of the periodic table.

Average elemental content of 85 cellular phones manufactured from 1998 to 2013

(excludes batteries; did not test for all elements)



Data source: Christian, B., Romanov, A., Romanova, I. & Turbini, L. Elemental Compositions of Over 80 Cell Phones. *J. Electron. Mater.* **43,** 4199–4213 (2014).

And it is not just about consumer electronics…

Energy generation

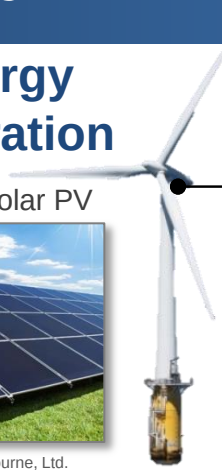
49 **In** Indium

31 **Ga** Gallium

34 **Se** Selenium

Thin-film solar PV

Photo credit: Testbourne, Ltd.



60 **Nd** Neodymium

66 **Dy** Dysprosium

Offshore direct drive wind turbine

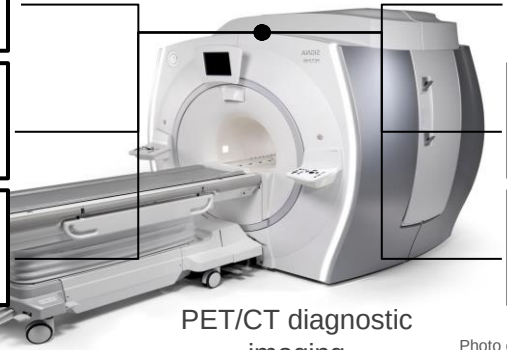
Photo credit: US DOE

Healthcare

64 **Gd** Gadolinium

63 **Eu** Europium

71 **Lu** Lutetium



58 **Ce** Cerium

65 **Tb** Terbium

39 **Y** Yttrium

PET/CT diagnostic imaging

Photo credit: GE Healthcare

Defense and national security

75 **Re** Rhenium

U.S. Air Force F-35A Lightning II Joint Strike Fighter

Photo credit: Master Sgt. John R. Nimmo, Sr.

Gen. III Ground Panoramic Night Vision Goggles

Photo credit: L3 Technologies, Inc.

32 **Ge** Germanium

31 **Ga** Gallium

33 **As** Arsenic

Transportation

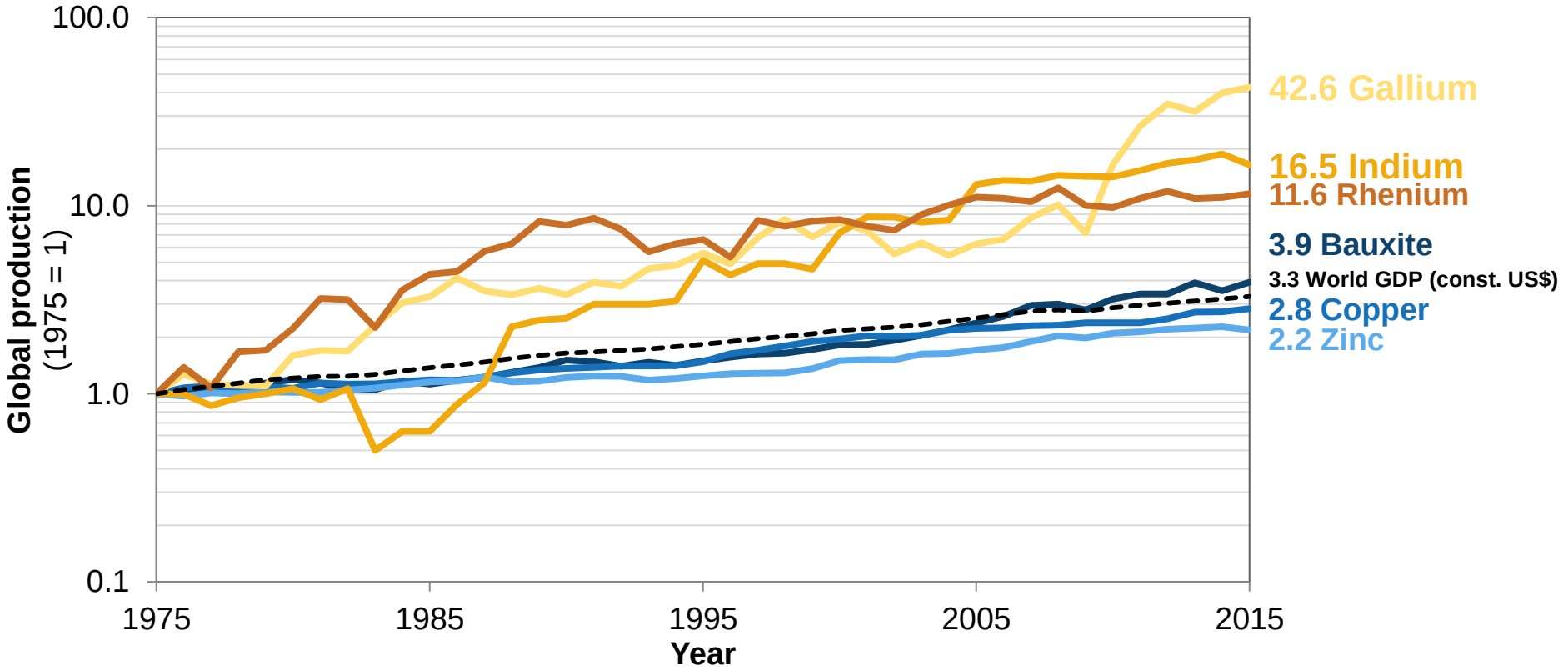
3 **Li** Lithium

27 **Co** Cobalt

Electric and hybrid vehicles

Photo credit: Telsa, Inc.

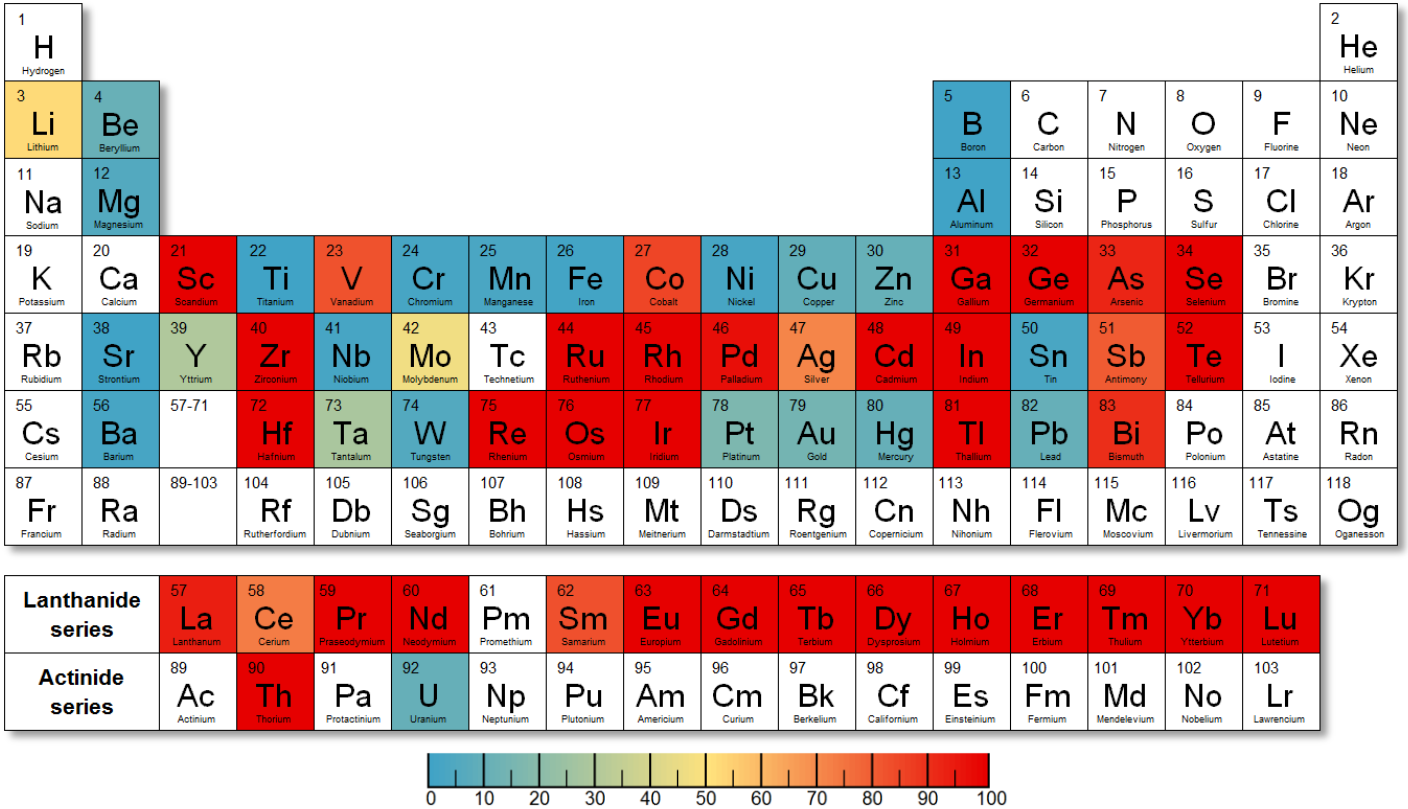
To meet demand, global production has increased markedly over the past few decades, especially for certain ‘minor metals.’



Data source: Kelly, T.D., and Matos, G.R., comps., 2017, Historical statistics for mineral and material commodities in the United States (2016 version): U.S. Geological Survey Data Series 140, available at https://minerals.usgs.gov/minerals/pubs/historical-statistics/. GDP data from World Bank.

Many of the mineral commodities required for advanced technologies are recovered only as byproducts during the processing of other minerals.

Share of element's primary production obtained as a byproduct



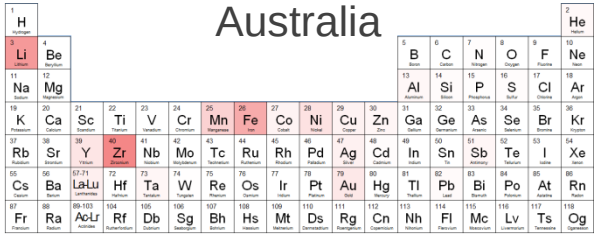
Nassar, N.T., Graedel, T.E., and Harper, E.M., 2015, By-product metals are technologically essential but have problematic supply: *Science Advances*, v. 1, no. 3, p. e1400180.

Production of many mineral commodities is highly concentrated in few countries.

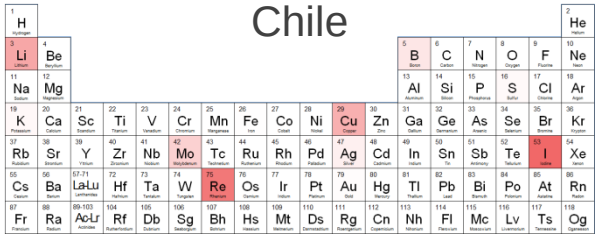
Share of each element's global production for various countries

(circa 2014)

Australia



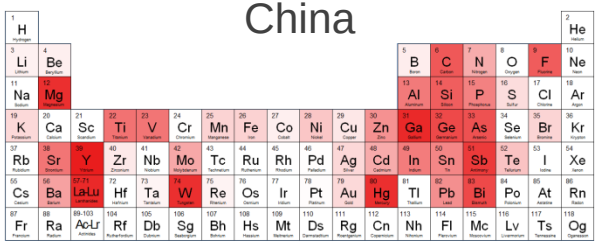
Chile



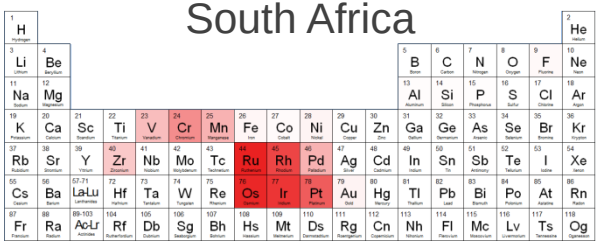
Russia

Brazil

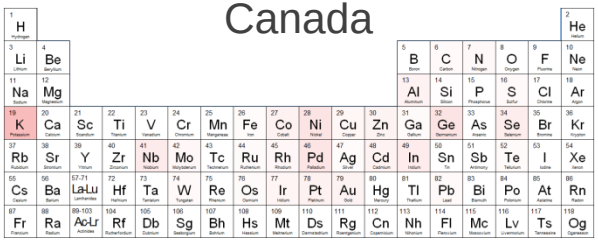
China



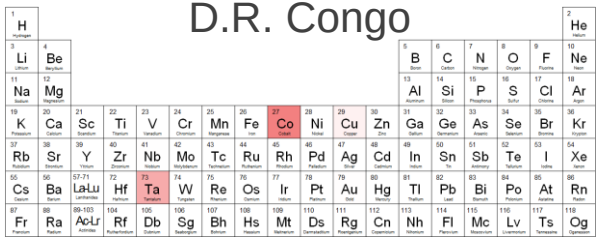
South Africa



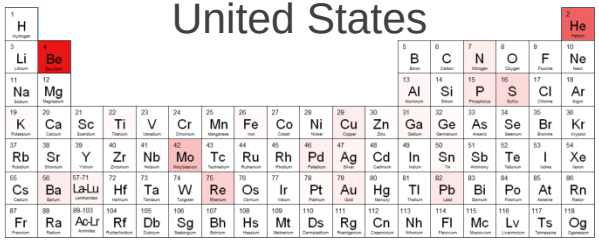
Canada

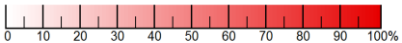


D.R. Congo



United States





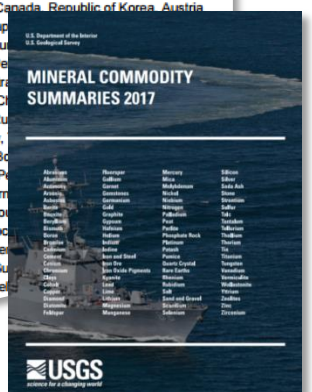
Data source: USGS, Minerals Yearbook

U.S. production for some commodities is withheld to avoid disclosing company proprietary information.

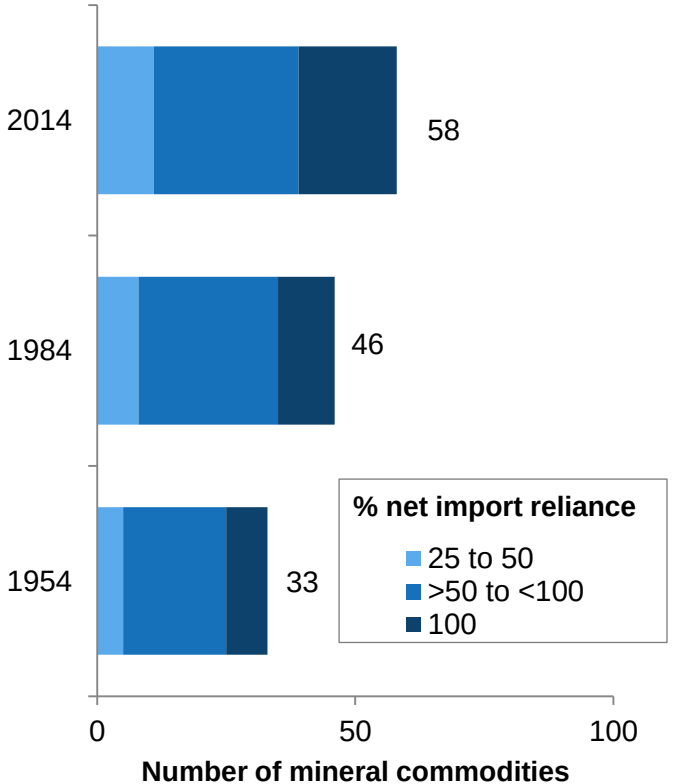
The United States is highly import reliant for a large and growing number of mineral commodities.

2016 U.S. NET IMPORT RELIANCE[1]

Commodity	Percent	Major import sources (2012–15)[2]
ARSENIC	100	China, Japan
ASBESTOS	100	Brazil
CESIUM	100	Canada
FLUORSPAR	100	Mexico, China, South Africa, Mongolia
GALLIUM	100	China, Germany, United Kingdom, Ukraine
GRAPHITE (natural)	100	China, Mexico, Canada, Brazil
INDIUM	100	Canada, China, France, Belgium
MANGANESE	100	South Africa, Gabon, Australia, Georgia
MICA, sheet (natural)	100	China, Brazil, Belgium, Austria
NIOBIUM (columbium)	100	Brazil, Canada
QUARTZ CRYSTAL (industrial)	100	China, Japan, Romania, United Kingdom
RARE EARTHS[3]	100	China, Estonia, France, Japan
RUBIDIUM	100	Canada
SCANDIUM	100	China
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	China, Kazakhstan, Germany, Thailand
THALLIUM	100	Germany, Russia
THORIUM	100	India, France, United Kingdom
VANADIUM	100	Czech Republic, Canada, Republic of Korea, Austria
YTTRIUM	100	China, Estonia, Jap
GEMSTONES	99	Israel, India, Belgiu
BISMUTH	95	China, Belgium, Pe
TITANIUM MINERAL CONCENTRATES	91	South Africa, Austra
POTASH	90	Canada, Russia, C
GERMANIUM	85	China, Belgium, Ru
STONE (dimension)	84	China, Brazil, Italy,
ANTIMONY	83	China, Thailand, Bo
ZINC	82	Canada, Mexico, P
RHENIUM	81	Chile, Poland, Gerr
GARNET (industrial)	79	Australia, India, So
BARITE	78	China, India, Moroc
FUSED ALUMINUM OXIDE (crude)	>75	China, Canada, Ve
BAUXITE	>75	Jamaica, Brazil, Gu
TELLURIUM	>75	Canada, China, Be
TIN	75	Peru, Indonesi
COBALT	74	Ch
DIAMOND (dust grit, and powder)	73	
PLATINUM	73	
IRON OXIDE PIGMENTS (natural)	>70	
IRON OXIDE PIGMENTS (synthetic)	>70	
	69	



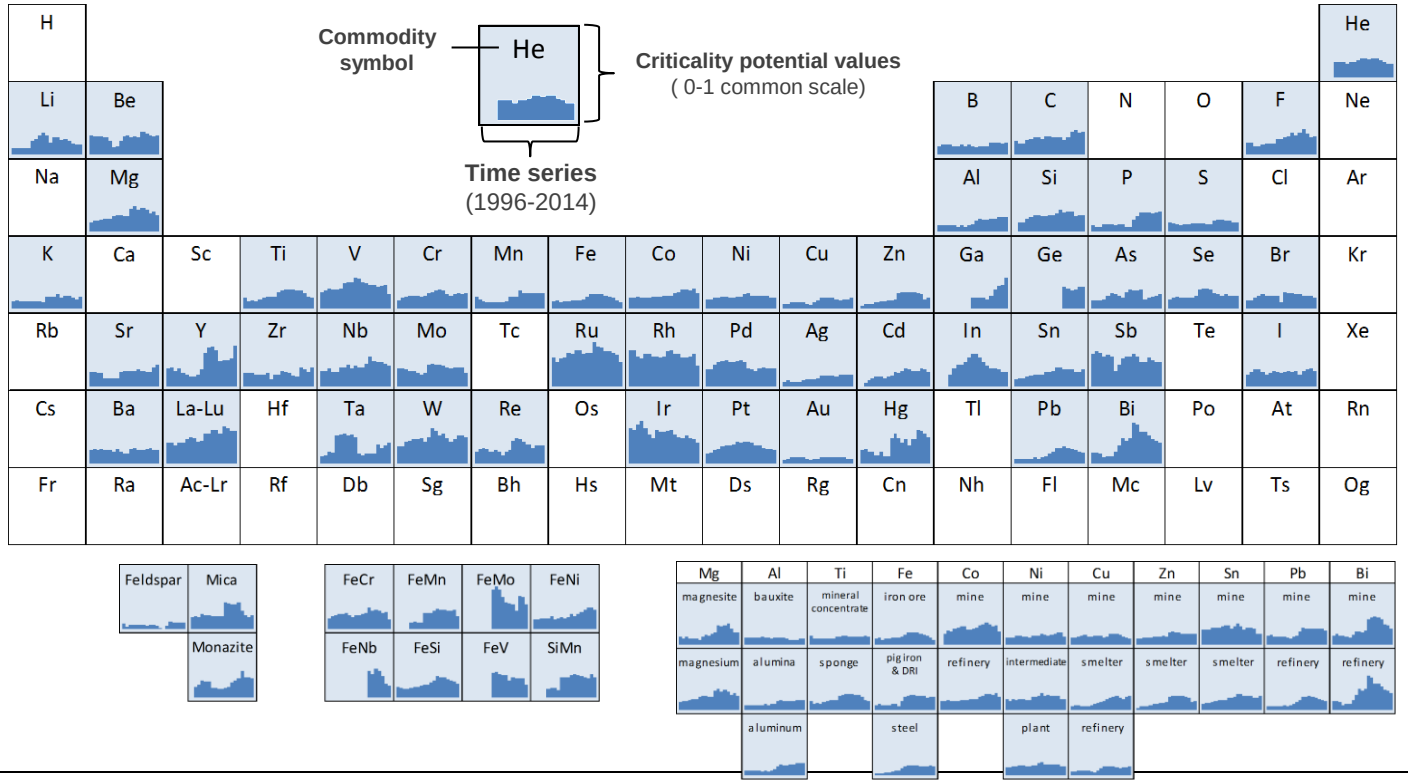
Growing U.S. net import reliance



U.S. Geological Survey, 2017, Mineral Commodity Summaries 2017, U.S. Geological Survey, Reston, VA, USA.
Fortier, S.M., DeYoung, J.H., J., Sangine, E.S., and K., S.E., 2015, Comparison of U.S. net import reliance for nonfuel mineral commodities—A 60-year retrospective (1954–1984–2014): U.S. Geological Survey.

As part of NSTC, we have developed a screening tool that helps identify commodities that are at an elevated risk of supply disruption.

National Science and Technology Council's Early Warning Screening

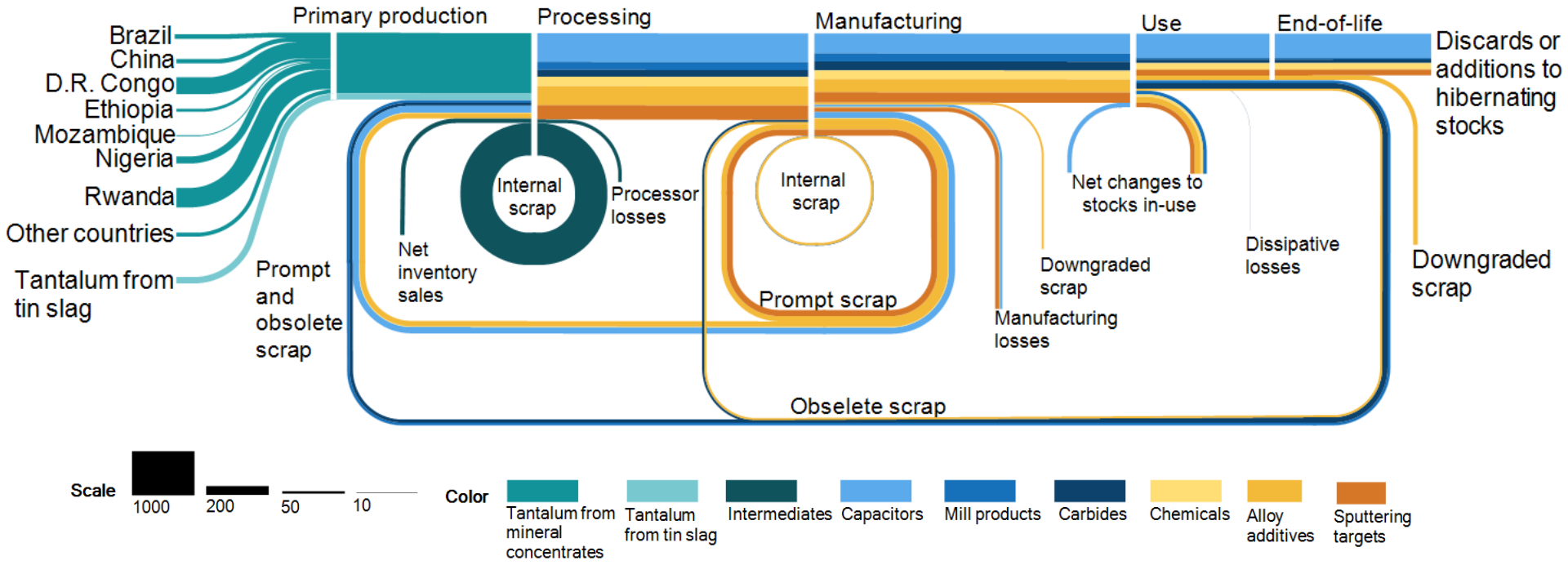


McCullough, E., and Nassar, N.T., 2017, Assessment of critical minerals: updated application of an early-warning screening methodology: *Mineral Economics*. doi: 10.1007/s13563-017-0119-6

Tracking mineral commodities throughout their life cycle provides insights into how the resource is being managed.

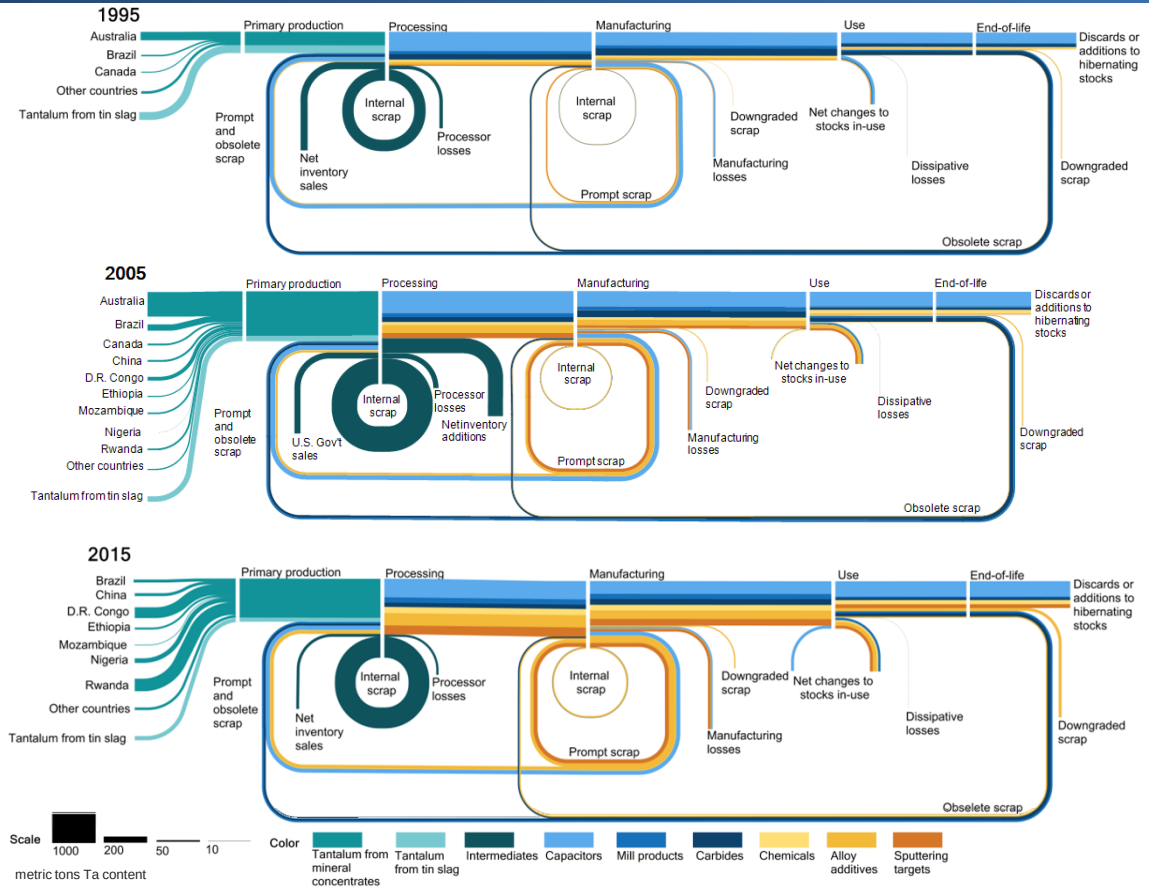
Global flows of tantalum

(metric tons of Ta content, circa 2015)

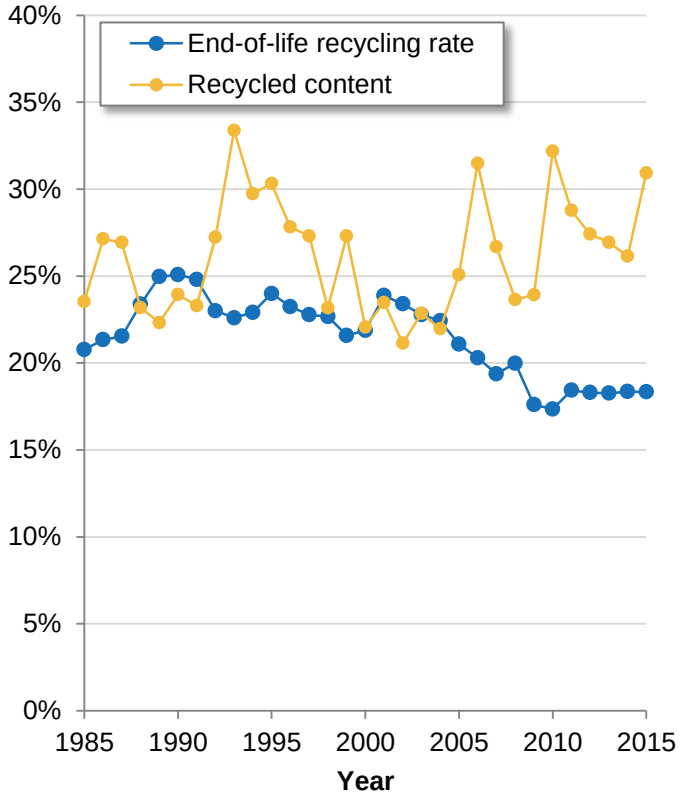


Nassar, N.T., 2017, Shifts and trends in the global anthropogenic stocks and flows of tantalum: Resources, Conservation and Recycling, v. 125, p. 233–250.

Tracking mineral commodity flows over time helps to identify trends and provides insights into the impacts of those trends.



Recycling metrics for tantalum over time

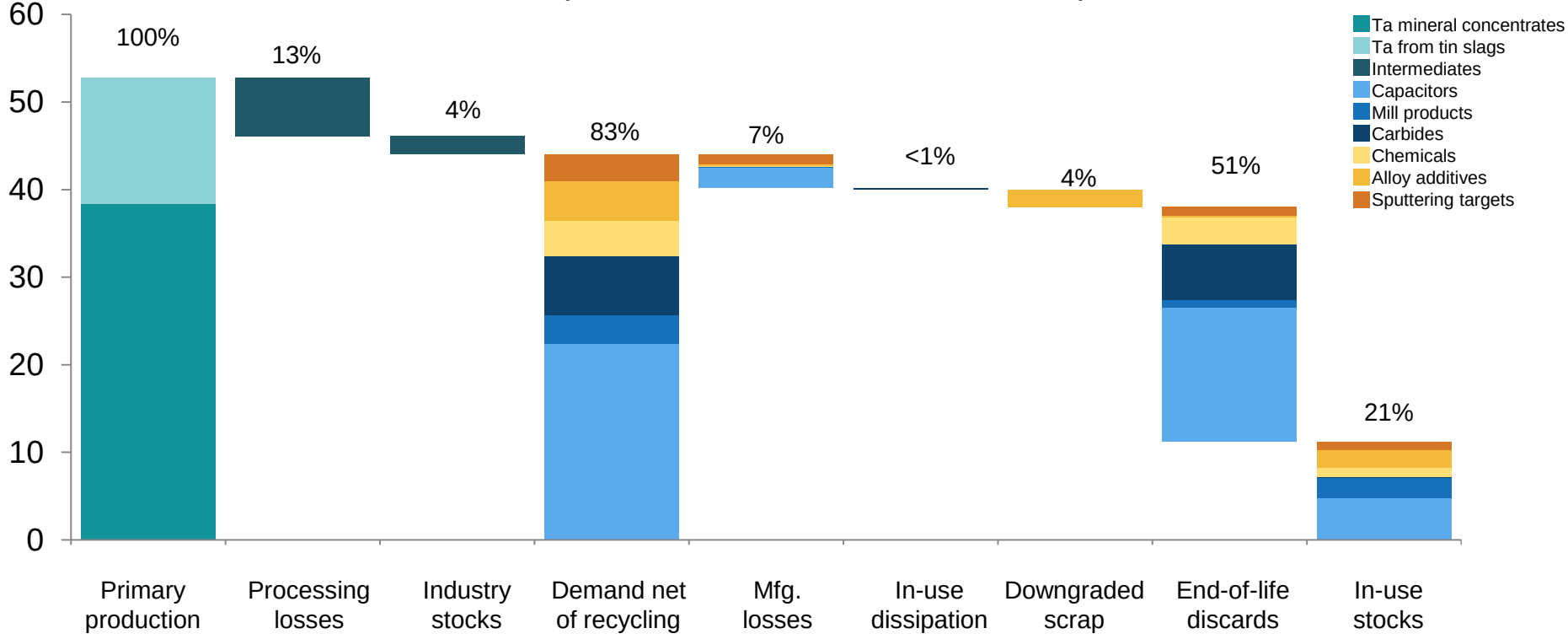


Nassar, N.T., 2017, Shifts and trends in the global anthropogenic stocks and flows of tantalum: Resources, Conservation and Recycling, v. 125, p. 233–250.

Assessing stocks of minerals contained in goods in-use provides an understanding of above-ground resource endowments, economic development, and recycling potential.

Status of tantalum above ground

(thousand metric tons Ta content)



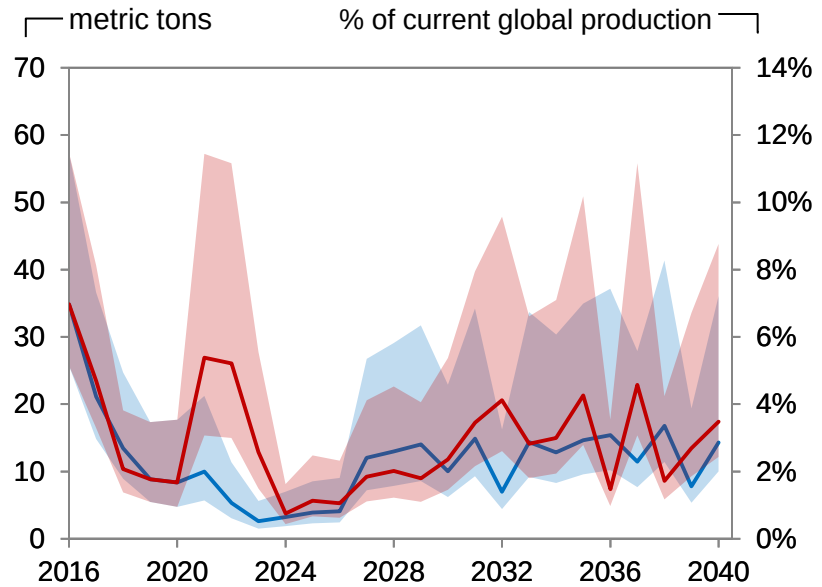
Nassar, N.T., 2017, Shifts and trends in the global anthropogenic stocks and flows of tantalum: Resources, Conservation and Recycling, v. 125, p. 233–250.

Supply and demand scenarios can be developed to better anticipate potential shortfalls.

Annual requirements for tellurium in U.S. CdTe up to 2040 under various scenarios

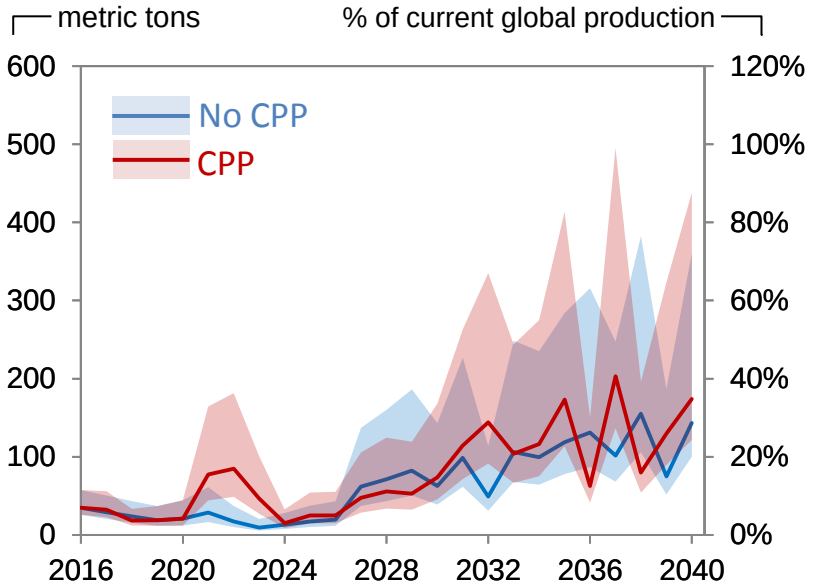
Constant market share

(Constant 5% market share of new U.S. solar PV capacity additions)



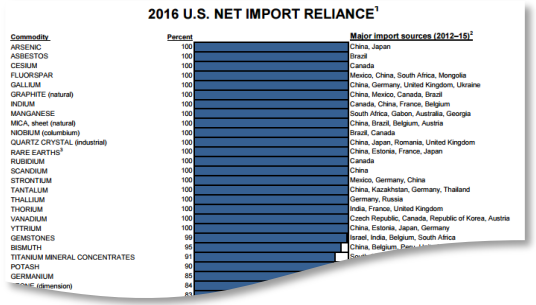
Growing market share

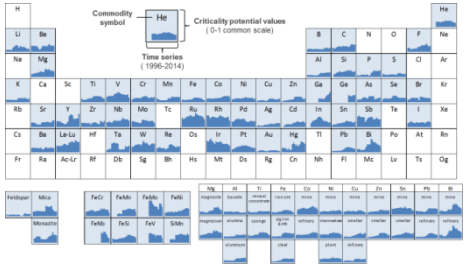
(Linearly increasing market share from 5 to 50%)

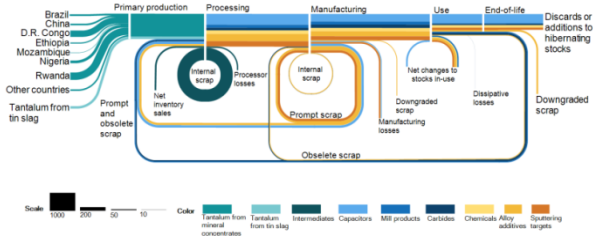


Nassar, N.T., Wilburn, D.R., and Goonan, T.G., 2016, Byproduct metal requirements for U.S. wind and solar photovoltaic electricity generation up to the year 2040 under various Clean Power Plan scenarios: Applied Energy, v. 183, p. 1209–1226.

Summary







- A combination of trends and issues raise concerns regarding the reliability of supply for certain non-fuel mineral commodities
- An early-warning screening has been developed to help identify minerals that are at the greatest risk of a supply disruption
- Assessments of mineral resources throughout their life cycle provide foundational knowledge for reducing that risk