

Minerals and Mines

or cheap as dirt

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What is a mineral?

Periodic Table of the Elements

Periodic Table of the Elements																			
<div><div>Atomic Number</div><div>Valence Charge</div><div>Symbol</div><div>Name</div><div>Atomic Mass</div></div>																			
1 IA 1A H Hydrogen 1.008	2 IIA 2A He Helium 4.003															18 VIIIA 8A			
3 Li Lithium 6.941	4 Be Beryllium 9.012													5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305													13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.833	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.972	35 Br Bromine 79.904	36 Kr Krypton 84.80		
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29		
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [209]	85 At Astatine [210]	86 Rn Radon [222]		
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [289]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [293]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown		

Lanthanide Series	57 La Lanthanum 138.905	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.965	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [252]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

What is a rare earth mineral?

Periodic Table of the Elements

																		Atomic Number		Valence Charge		Symbol		Name		Atomic Mass	
1 IA 1A	2 IIA 2A															13 IIIA 3A	14 IIIA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A						
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																		119 Uue Ununennium [289]	120 Uuh Unbinilium [292]	121 Uut Untrium [293]	122 Uuq Unquadrium [294]	123 Uub Unpentium [295]	124 Uub Unsextium [296]	125 Uub Unseptium [297]	126 Uub Unoctium [298]		
																		127 Uus Unseptium [299]	128 Uuo Unoctium [300]	129 Uuh Unenneium [301]	130 Uuo Unenneium [302]	131 Uuh Unenneium [303]	132 Uuo Unenneium [304]	133 Uuh Unenneium [305]	134 Uuo Unenneium [306]		
																		135 Uuh Unenneium [307]	136 Uuo Unenneium [308]	137 Uuh Unenneium [309]	138 Uuo Unenneium [310]	139 Uuh Unenneium [311]	140 Uuo Unenneium [312]	141 Uuh Unenneium [313]	142 Uuo Unenneium [314]		
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																		239 Uuh Unenneium [411]	240 Uuo Unenneium [412]	241 Uuh Unenneium [413]	242 Uuo Unenneium [414]	243 Uuh Unenneium [415]	244 Uuo Unenneium [416]	245 Uuh Unenneium [417]	246 Uuo Unenneium [418]		
																		247 Uuh Unenneium [419]	248 Uuo Unenneium [420]	249 Uuh Unenneium [421]	250 Uuo Unenneium [422]	251 Uuh Unenneium [423]	252 Uuo Unenneium [424]	253 Uuh Unenneium [425]	254 Uuo Unenneium [426]		
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																		263 Uuh Unenneium [435]	264 Uuo Unenneium [436]	265 Uuh Unenneium [437]	266 Uuo Unenneium [438]	267 Uuh Unenneium [439]	268 Uuo Unenneium [440]	269 Uuh Unenneium [441]	270 Uuo Unenneium [442]		
																		271 Uuh Unenneium [443]	272 Uuo Unenneium [444]	273 Uuh Unenneium [445]	274 Uuo Unenneium [446]	275 Uuh Unenneium [447]	276 Uuo Unenneium [448]	277 Uuh Unenneium [449]	278 Uuo Unenneium [450]		
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																		303 Uuh Unenneium [475]	304 Uuo Unenneium [476]	305 Uuh Unenneium [477]	306 Uuo Unenneium [478]	307 Uuh Unenneium [479]	308 Uuo Unenneium [480]	309 Uuh Unenneium [481]	310 Uuo Unenneium [482]		
																		311 Uuh Unenneium [483]	312 Uuo Unenneium [484]	313 Uuh Unenneium [485]	314 Uuo Unenneium [486]	315 Uuh Unenneium [487]	316 Uuo Unenneium [488]	317 Uuh Unenneium [489]	318 Uuo Unenneium [490]		
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																		431 Uuh Unenneium [603]	432 Uuo Unenneium [604]	433 Uuh Unenneium [605]	434 Uuo Unenneium [606]	435 Uuh Unenneium [607]	436 Uuo Unenneium [608]	437 Uuh Unenneium [609]	438 Uuo Unenneium [610]		
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																		479 Uuh Unenneium [651]	480 Uuo Unenneium [652]	481 Uuh Unenneium [653]	482 Uuo Unenneium [654]	483 Uuh Unenneium [655]	484 Uuo Unenneium [656]	485 Uuh Unenneium [657]	486 Uuo Unenneium [658]		
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																		495 Uuh Unenneium [667]	496 Uuo Unenneium [668]	497 Uuh Unenneium [669]	498 Uuo Unenneium [670]	499 Uuh Unenneium [6					

Why are rare earth minerals important?



Rare-earth elements (REEs) are used in the components of many devices used daily in our modern society, such as: the screens of smart phones, computers, and flat panel televisions; the motors of computer drives; batteries of hybrid and electric cars; and new generation light bulbs. Lanthanum-based catalysts are employed in petroleum refining. Large wind turbines use generators that contain strong permanent magnets composed of neodymium-iron-boron. Photographs used with permission from PHOTOS.com.

Why are rare earth minerals important?

Table 1. Materials in Clean Energy Technologies and Components

		CLEAN ENERGY TECHNOLOGIES AND COMPONENTS				
		Solar Cells	Wind Turbines	Vehicles		Lighting
MATERIAL		PV films	Magnets	Magnets	Batteries	Phosphors
Rare Earth Elements	Lanthanum				●	●
	Cerium				●	●
	Praseodymium		●	●	●	
	Neodymium		●	●	●	
	Samarium		●	●		
	Europium					●
	Terbium					●
	Dysprosium		●	●		
	Yttrium					●
Indium		●				
Gallium		●				
Tellurium		●				
Cobalt					●	
Lithium					●	

What is a *critical* mineral?

Figure 1. Short-Term (0–5 years)
Criticality Matrix

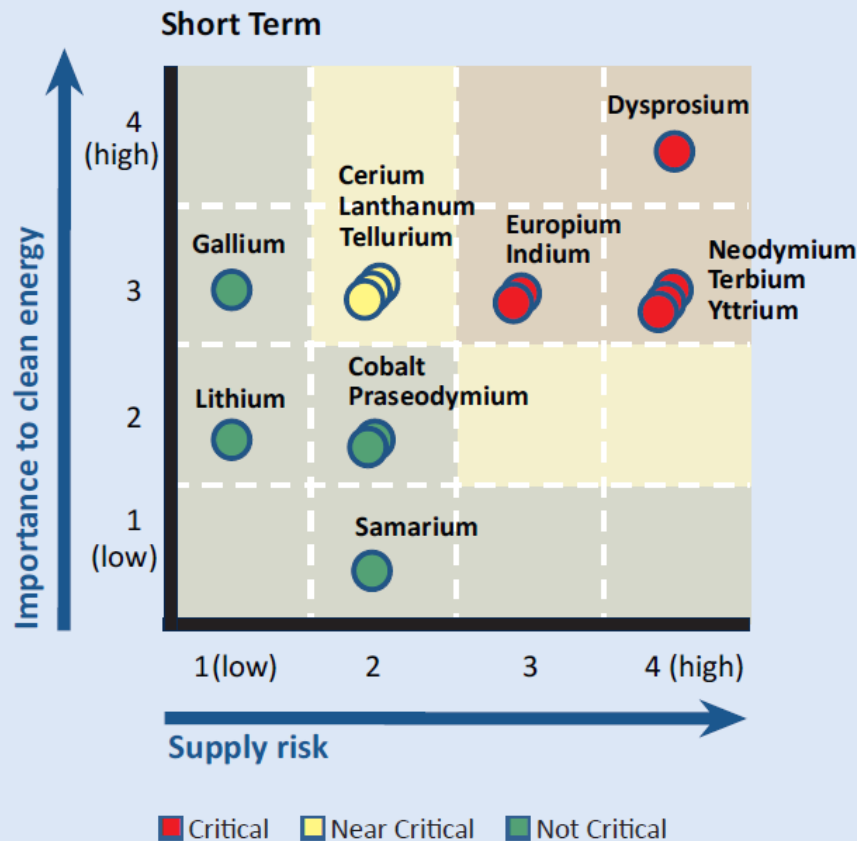
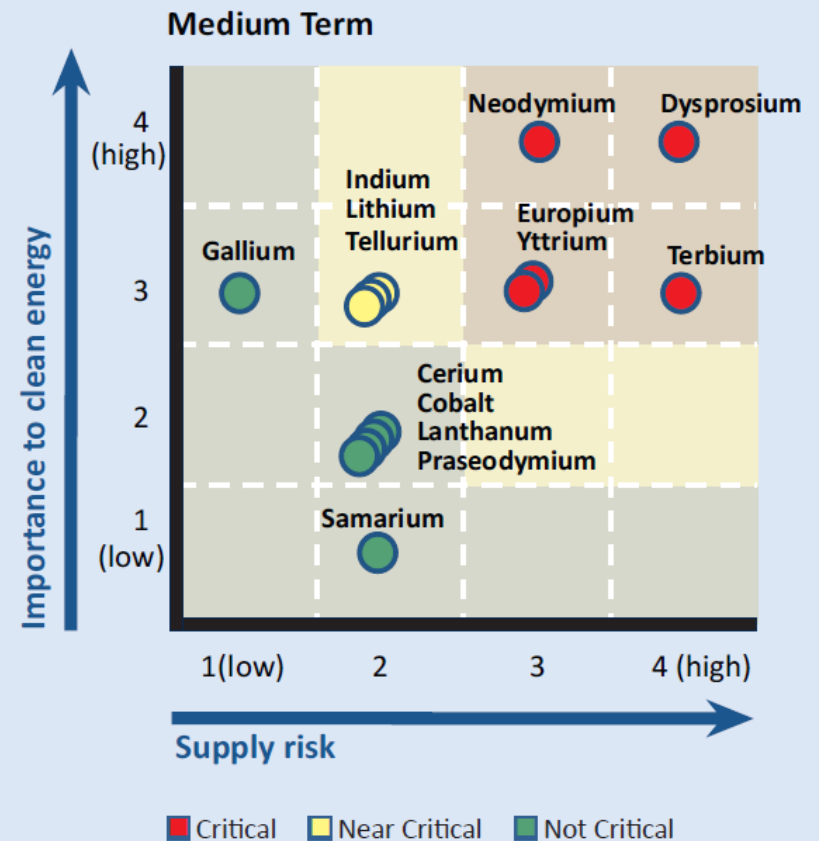


Figure 2. Medium-Term (5–15 years)
Criticality Matrix



How bad is the problem?

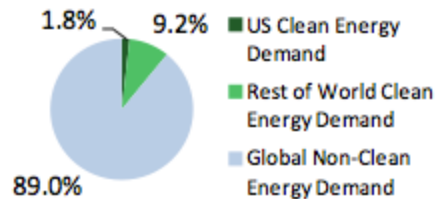
Dysprosium Oxide Future Supply and Demand

2011 Update

Supply

- 2015 Estimated Supply ---
- Plus Mount Weld - . - .
- Plus Mountain Pass Phase I
- 2010 Supply _____

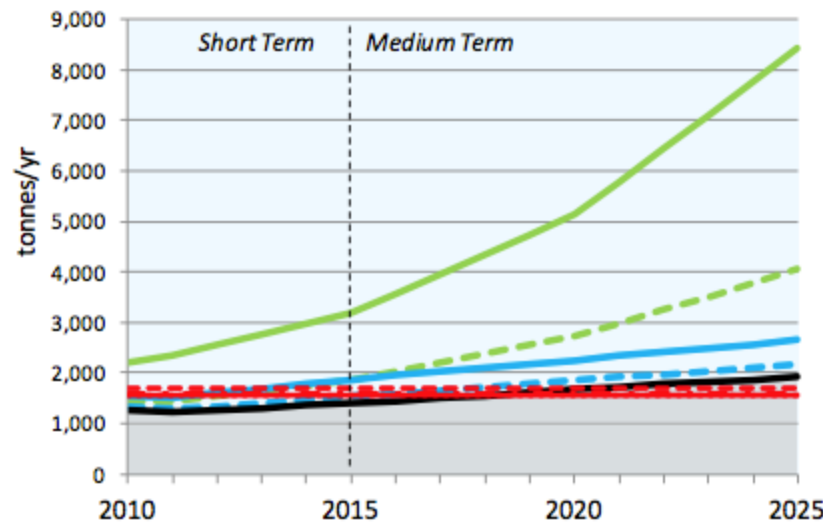
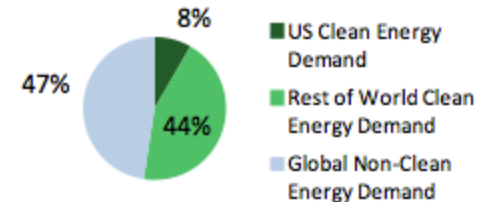
2010 - Trajectory C

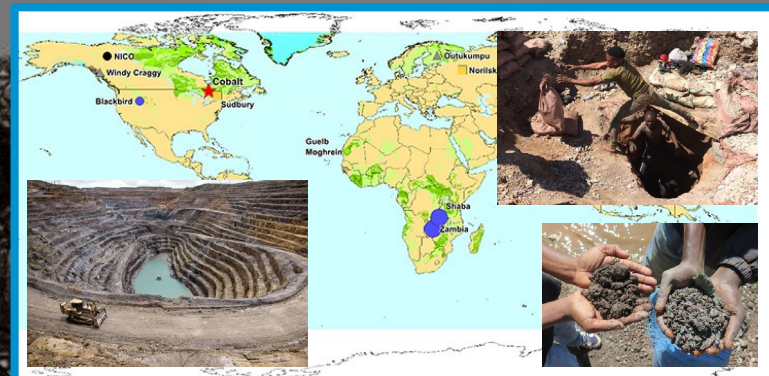
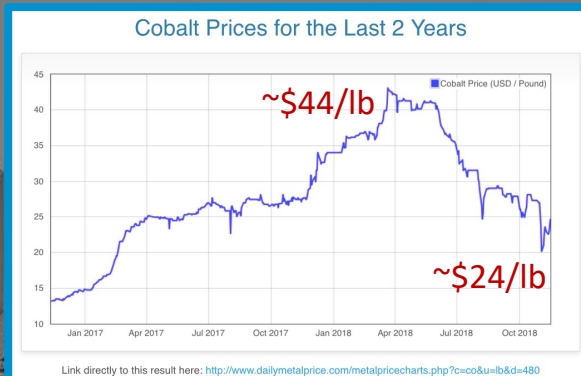
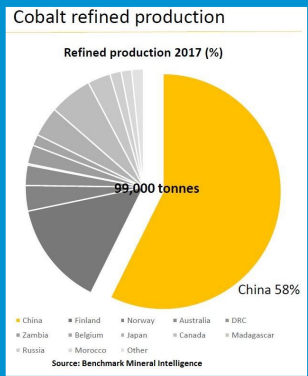


Demand

- Trajectory D _____
- Trajectory C - - - - -
- Trajectory B _____
- Trajectory A - - - - -
- Non-Clean Energy Use _____

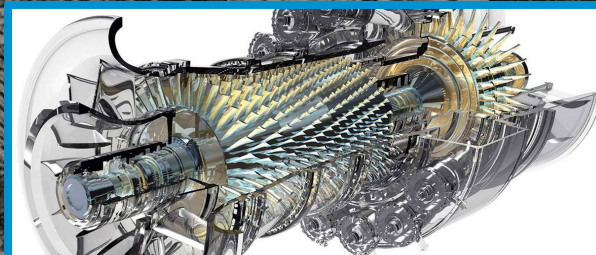
2025 - Trajectory C





Known Reserves:

- US - 23K tons
- Congo - 3.5M tons
- Australia - 1.2M tons
- World - 7.1M tons



Interesting Cobalt Facts:

- Current design of supply chain makes it difficult to track ethically sourced cobalt.
- Large companies are cutting out the middleman and securing contracts directly with mines
- Rise in price during 2017 and into 2018 due to jet engines and failing metal supplies, not demand of EVs

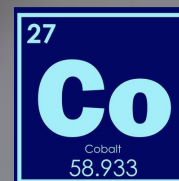
Potential Reserves:

- 1M tons in US
- 25M tons worldwide



How running out will impact society:

- DRC Economic Impact | Increased need for cobalt recycling | Increased innovation in energy storage technology
- "...even with a very conservative estimate of 10 million EV sales in 2025, the demand for cobalt that year could reach 330,000 metric tons, whereas the available supply at that time would be at most 290,000 metric tons."



29
Cu
copper
63.546(3)



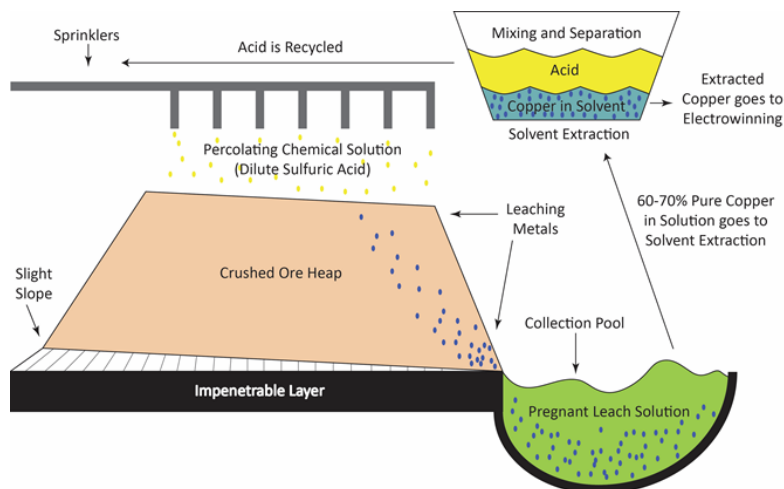
Amount Used

2017 - United States 1.85 million metric tons of unmanufactured copper

Cost - \$2.81 (11/15/18)



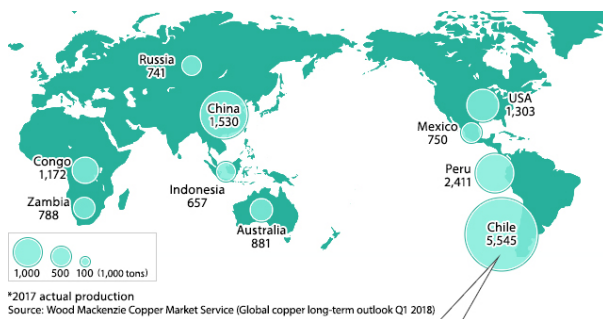
How do we get it



Known and Potential Reserves

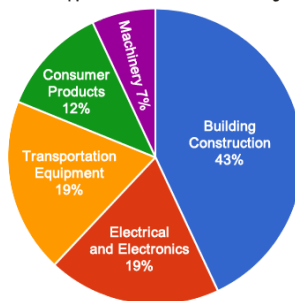
Region	Deposit type	Tract extent (km²)	Undiscovered resources (Mt)				Identified resources (Mt)
			90 %	50 %	10 %	Mean	
South America	Porphyry	1,200,000	500	730	1,000	750	810
	Sediment-hosted	99,000					0.51
Central America and the Caribbean	Porphyry	540,000	78	150	280	170	42
North America	Porphyry	3,200,000	250	370	540	400	470
	Sediment-hosted	450,000	15	48	110	57	18
Northeast Asia	Porphyry	2,300,000	76	220	500	260	8.8
North Central Asia	Porphyry	3,200,000	210	360	590	440	130
	Sediment-hosted	180,000	22	49	90	53	48
South Central Asia and Indochina	Porphyry	3,800,000	280	490	770	510	63
	Sediment-hosted	29,000					4.5
Southeast Asia Archipelagos	Porphyry	850,000	180	290	430	300	130
Australia	Porphyry	580,000	1.9	14	54	21	15
Eastern Europe and Southwestern Asia	Porphyry	1,200,000	130	220	370	240	110
	Sediment-hosted	4,800	0.052	4.8	36	13	6.4
Western Europe	Porphyry	73,000					1.6
	Sediment-hosted	190,000	38	110	230	120	77
Africa and the Middle East	Sediment-hosted	200,000	81	150	260	160	160
Total copper						3,500	2,100

Where is it from



How is it used?

Uses of Copper in the United States During 2017



What will happen if we run out?



Fun Fact





Amount used per year: Averaged over 7.5 million metric tons 2010-2017



Cost per pound: 99.9% pure = \$50/lb | Hyperpure = \$1,600/lb



Where we get it from: 2/3 of global production in 2017 was in China



How we get it: Silica and a carbon material like 'coke' are submerged in an electric arc furnace, causing a reaction where the oxygen is removed, leaving behind silicon



How we use it: Steel, cast iron, superalloys, other alloys, silicones, polymers, polysilicon (for PVs), highly refined silicon electronics and semiconductors



Known reserves: "World and domestic resources for making silicon are abundant... adequate to supply world requirements for many decades" (USGS, 2007)



Potential reserves: "Since the world has an almost limitless supply of both of these (quartz and carbon), in terms of raw materials, the world has an almost limitless silicon supply"



How running out will impact our society: "Scientists find new semiconductor materials that could replace silicon in the future" (2017)



Quite Interesting fact about Silicon: it's the 2nd most common* element in the Earth's crust (1st is Oxygen), 7th most abundant(element in the universe (* = by mass)

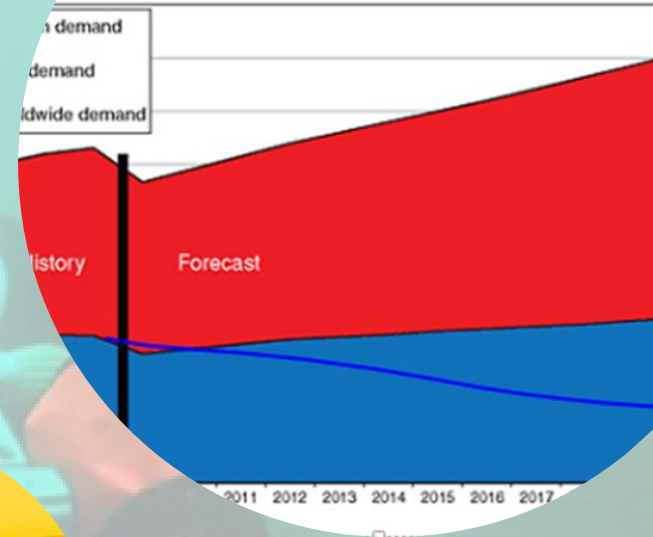
Sources

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- <http://www.madehow.com/Volume-6/Silicon.html>
- <https://minerals.usgs.gov/minerals/pubs/commodity/silicon/silicmcs07.pdf>
- <https://www.neowin.net/news/scientists-find-new-semiconductor-materials-that-could-replace-silicon-in-the-future/>
- <https://seekingalpha.com/article/3322725-silicon-solar-power-provides-huge-potential-for-long-term-growth?page=2>

Helium

- Global demand has risen to over 8B ft³/year
- \$119/1000 ft³
- Recovered through the extraction of Natural Gas
- Primarily used in Cryogenic cooling
- US National Helium Reserve accounts for 30% of the world's helium

²
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Helium
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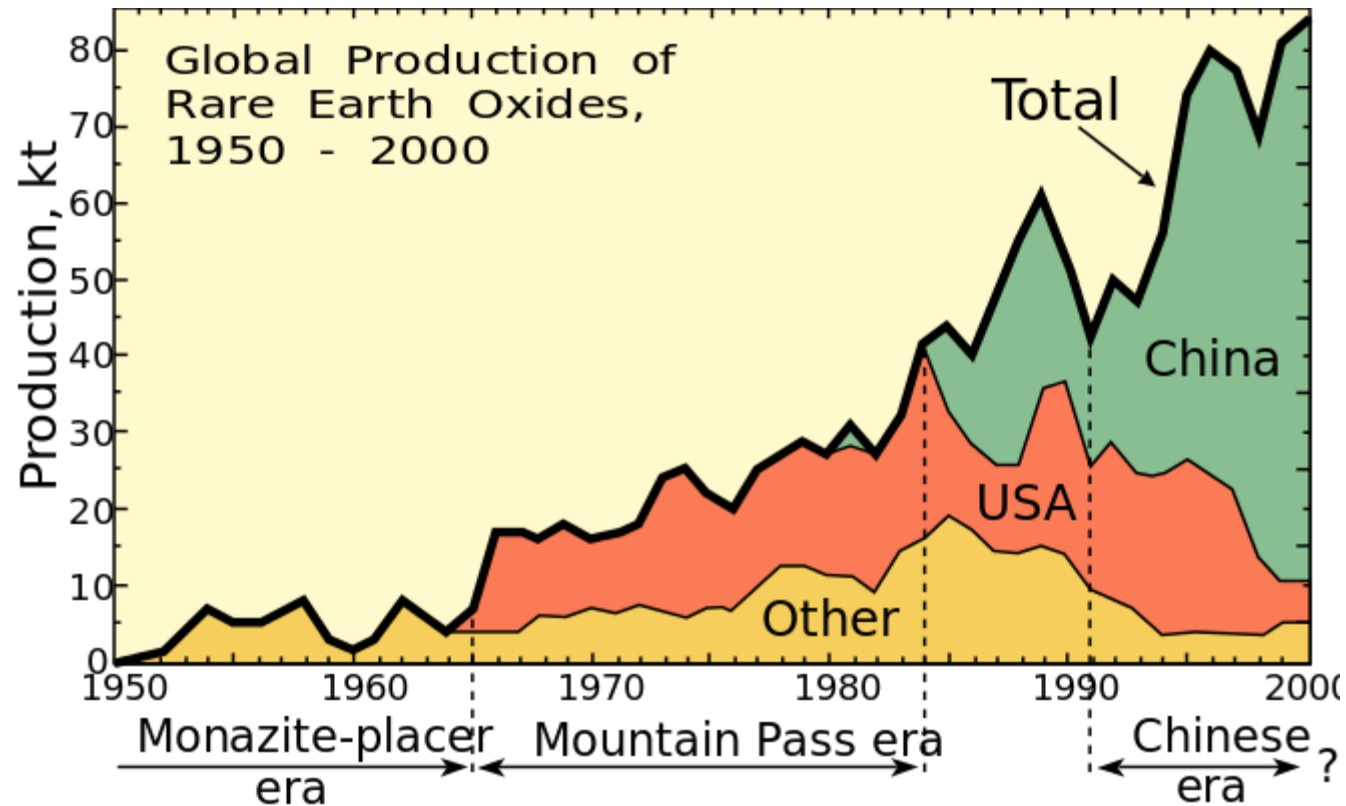


Neodymium (Nd)



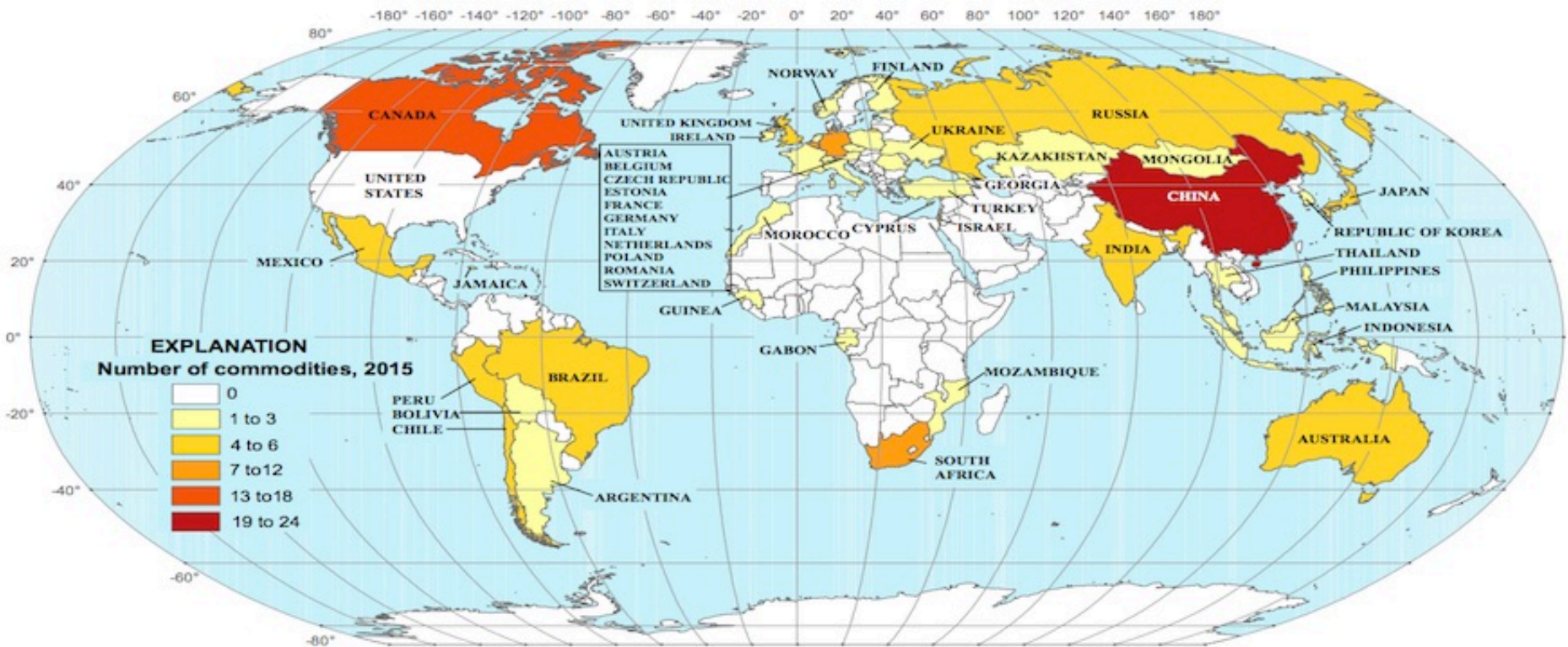
- **Amount used per year:** ~40,000 tons per year
- **Cost per pound:** \$21.6/lbs → (\$47.5/kg Q3 2017)
- **Where we get it from:** “Rare Earth Element” Present in ore minerals; monazite and bastnäsite – China produces 80% of the worlds supply
- **How we get it:** Extracted by ion exchange and solvent extraction processes.
- **How we use it:** Used in alloys for powerful permanent magnets, lasers, and to color glazes and glass (welders goggles)
- **Known reserves:** China (44 million MT), Brazil (22M MT), Russia (18M MT), India (6.9M MT), Australia (3.4M MT)
- **Potential reserves:** Greenland, Canada, Sweden, Vietnam, USA, the Amazon, asteroids
- **How running out will impact our society:** Without rare earth elements, we would lack miniaturization capabilities (i.e. computers the size of classrooms vs. size of smartphone)
- **Interesting fact:** “For an iPhone to vibrate, for AirPods to play music, for wind turbines to generate power and for a Toyota Prius or Tesla Model 3's motor to spin, they need powerful magnets. If you combine neodymium with iron and boron, you can make a neodymium-iron-boron magnet, which is the most powerful type of permanent magnet ever created”

Where are rare earth minerals located?



95% come from China. No US-plants

MAJOR IMPORT SOURCES OF NONFUEL MINERAL COMMODITIES FOR WHICH THE UNITED STATES WAS GREATER THAN 50% NET IMPORT RELIANT IN 2015



Source: U.S. Geological Survey

What are conflict minerals?

Coltan
(For tantalum)



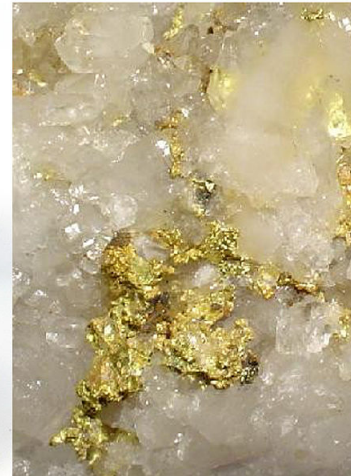
Cassiterite
(for tin)



Wolframite
(For tungsten)



Gold Ore



*Democratic Republic of Congo
(sold to perpetuate fighting)*

Rare Earth

Copper

Gold

Coal



Copper



Gold



Coal



Rare Earth



Thank You