# Minerals and Mines

or cheap as dirt

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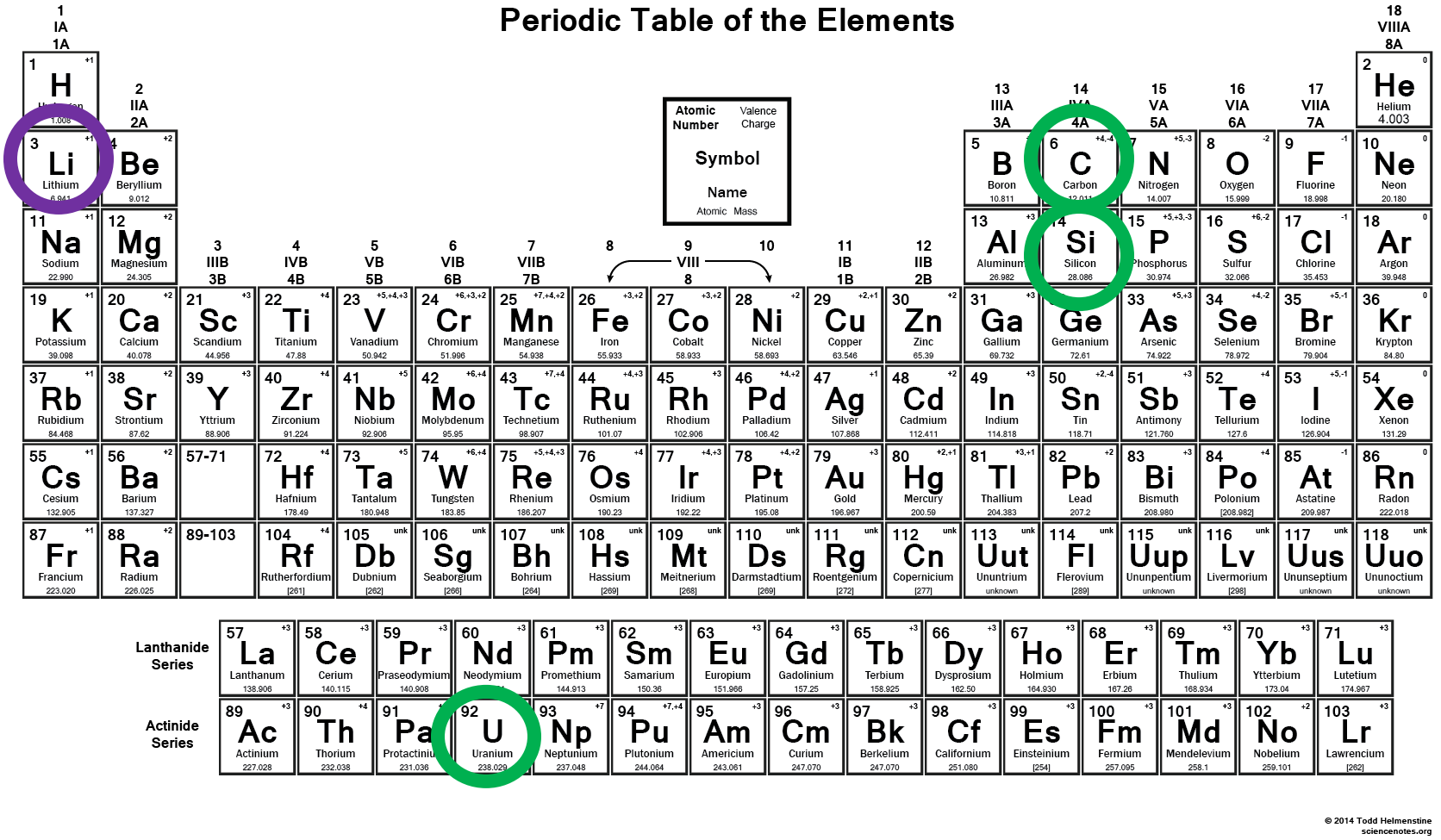
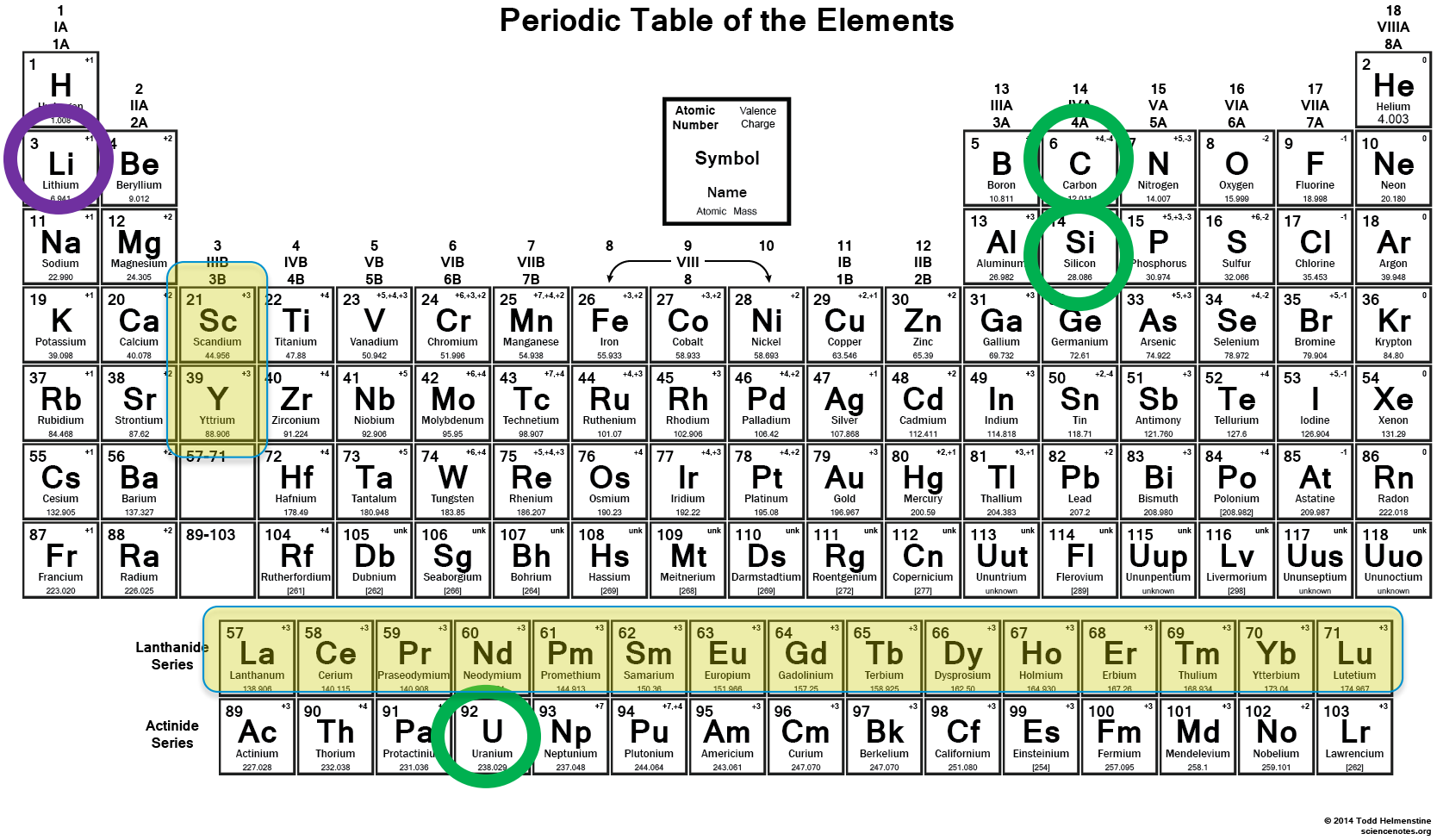
# What is a mineral?



# What is a rare earth mineral?



# 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.

https://pubs.usgs.gov/fs/2014/3078/pdf/fs2014-3078.pdf

# 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 | | | | ● | |

https://energy.gov/sites/prod/files/edg/news/documents/Critical_Materials_Summary.pdf

# What is a *critical* mineral?

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

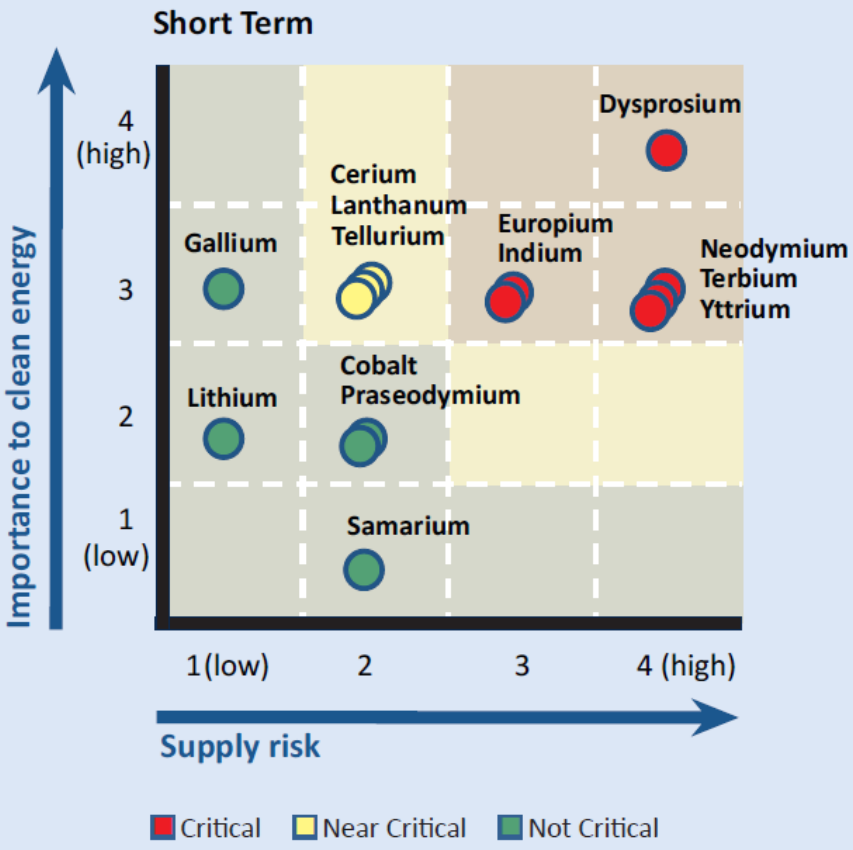
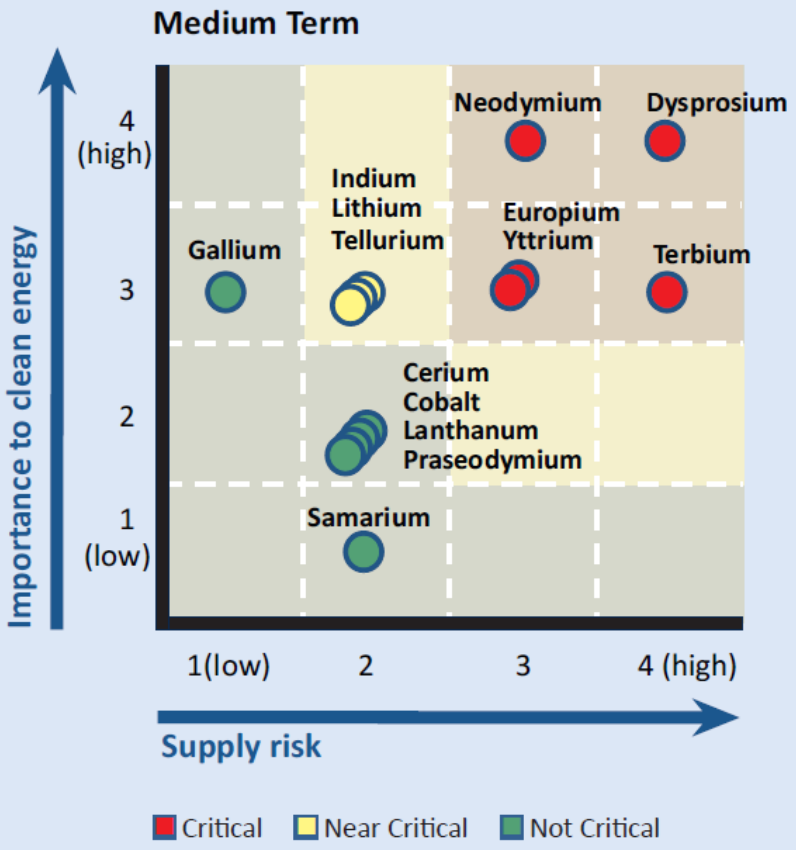
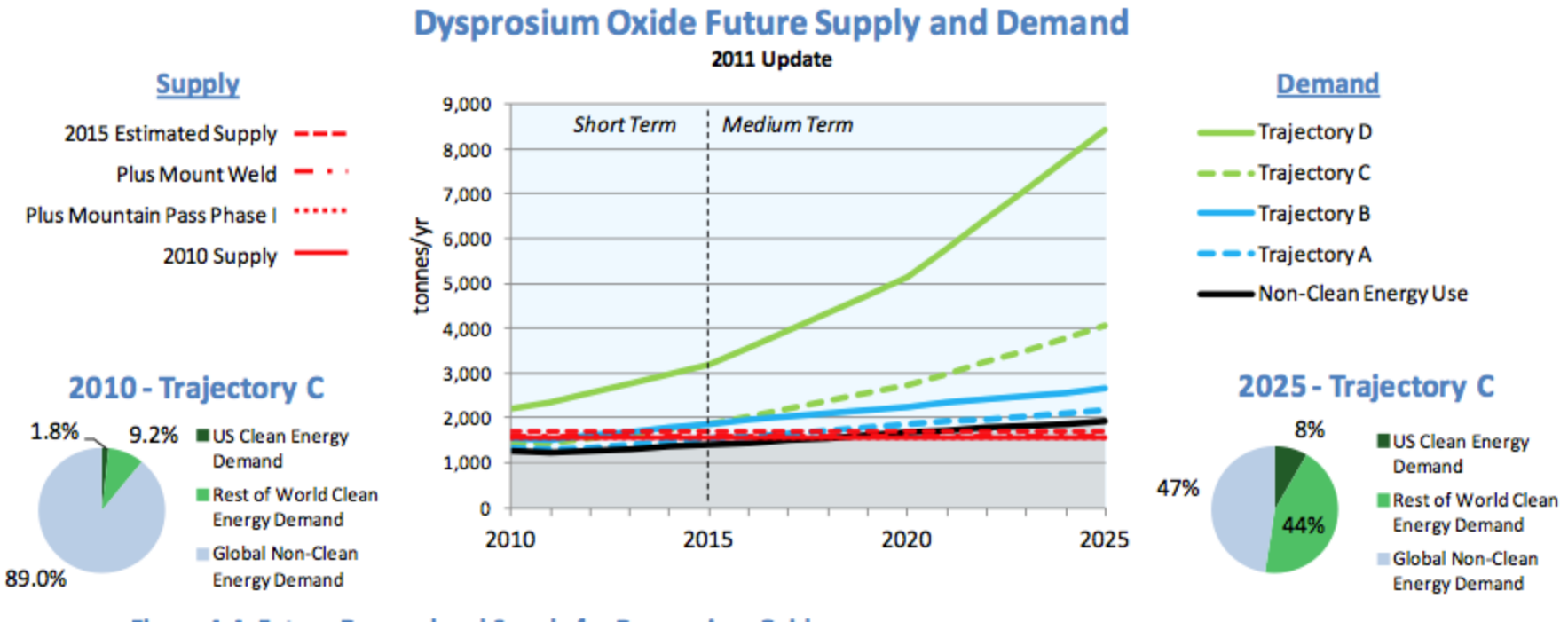


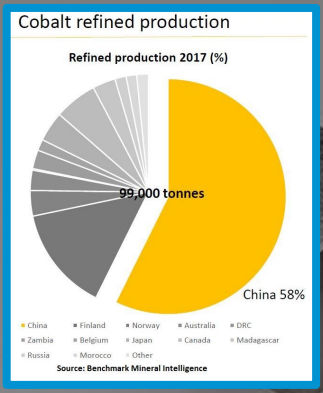

*Figure 2. Medium-Term (5–15 years) Criticality Matrix*

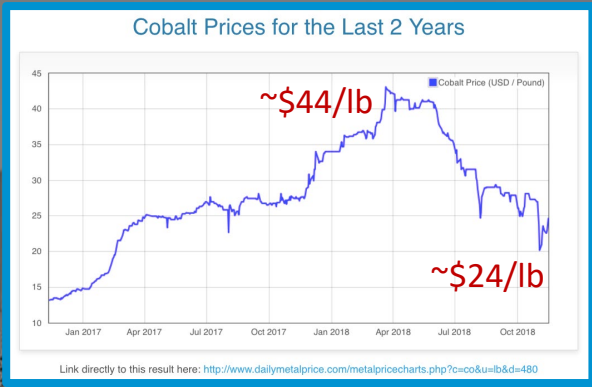


# How bad is the problem?




http://web.mit.edu/12.000/www/m2016/finalwebsite/problems/ree.html

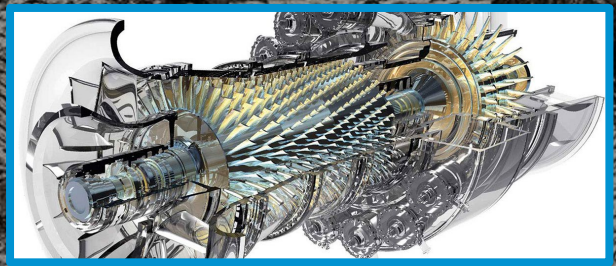




## Known Reserves:

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



## Potential Reserves:

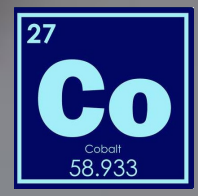
- 1M tons in US
- 25M tons worldwide


## 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

## 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)



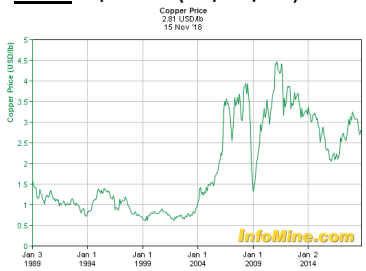




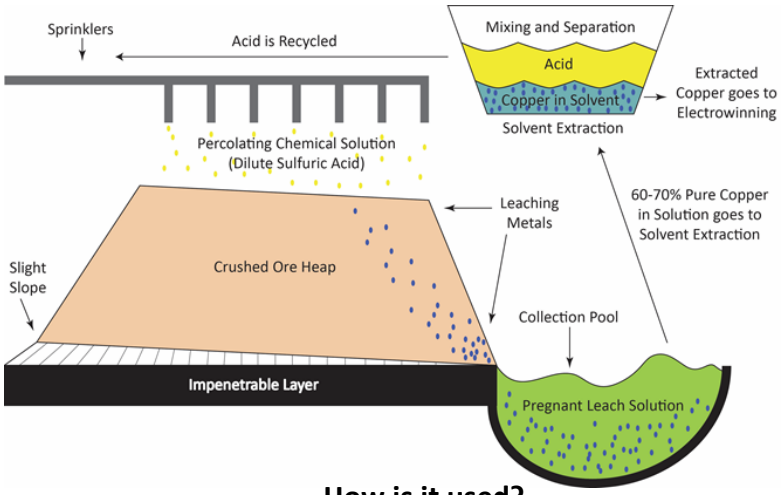

## Amount Used

2017 - United States 1.85 million metric tons of unmanufactured copper

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



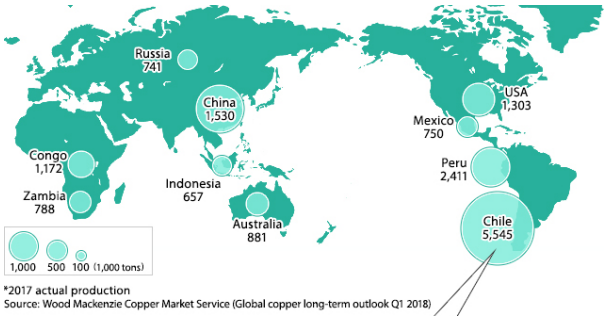

## How do we get it




## 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** |

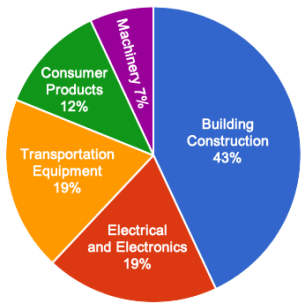
## Where is it from




*2017 actual production
Source: Wood Mackenzie Copper Market Service (Global copper long-term outlook Q1 2018)

## 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)

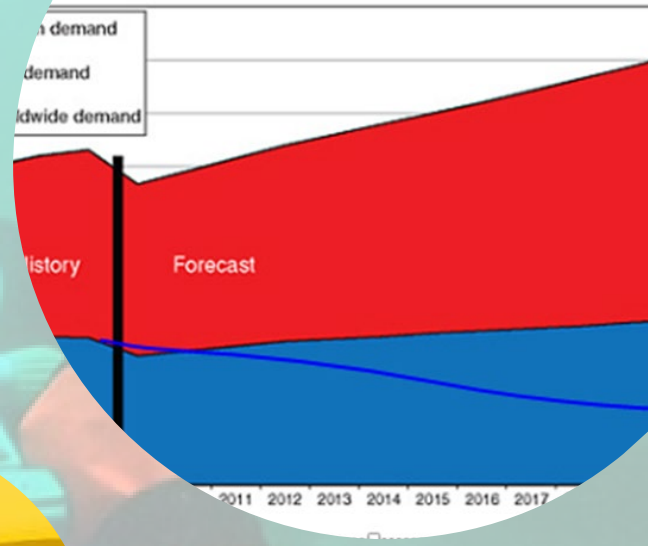
**Quite Interesting fact about Silicon:** it's the 2nd most common* element in the Earth's crust (1st is Oxygen), 7th most abundant( element in the universe (* = by mass)

# Sources


- https://www.statista.com/topics/1959/silicon/
- https://www.statista.com/statistics/573585/global-silicon-production/
- 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

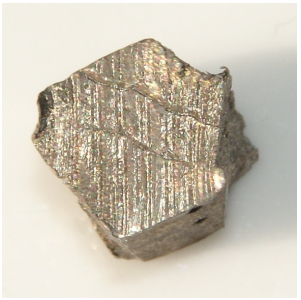
# Helium

- Global demand has risen to over 8B $ft^3$/year
- \$119/1000 $ft^3$
- Recovered through the extraction of Natural Gas
- Primarily used in Cryogenic cooling
- US National Helium Reserve accounts for 30% of the worlds's helium



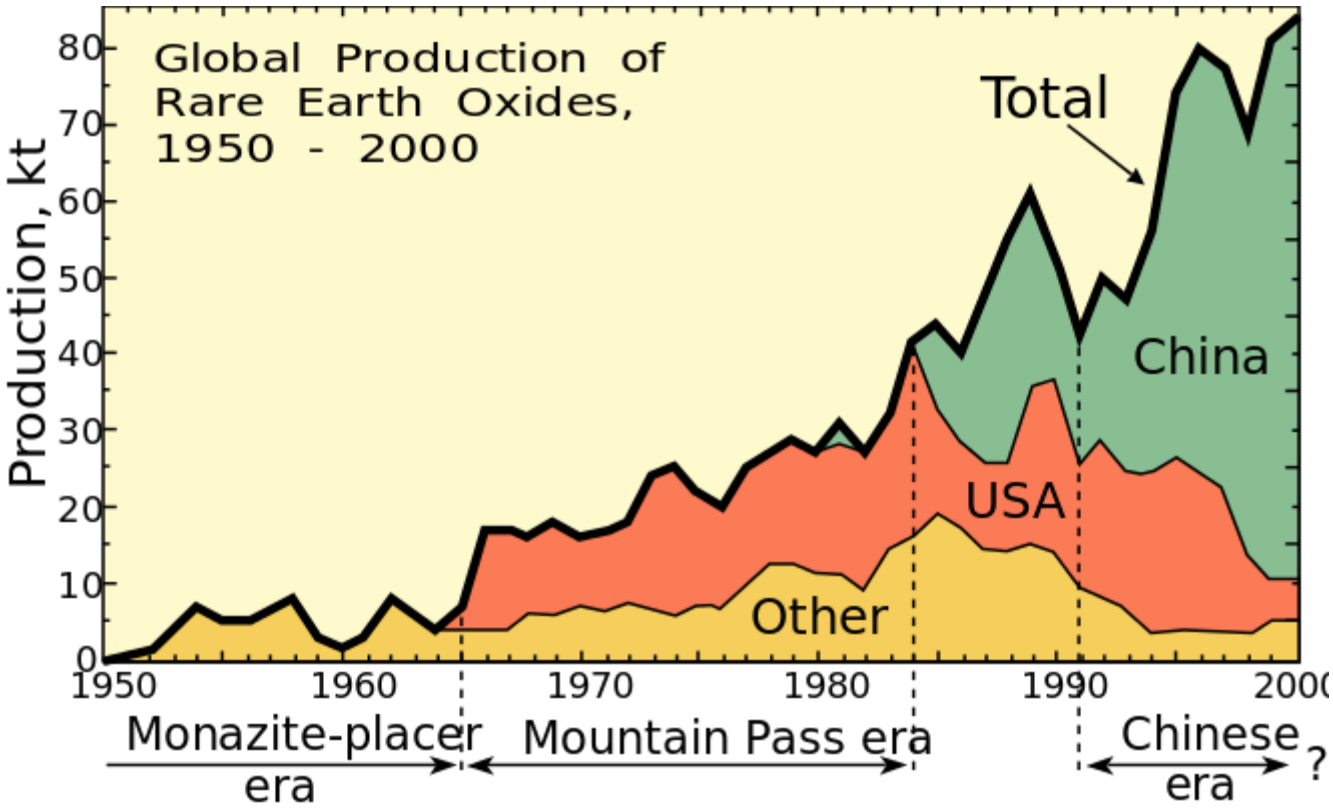


# Neodymium (Nd)



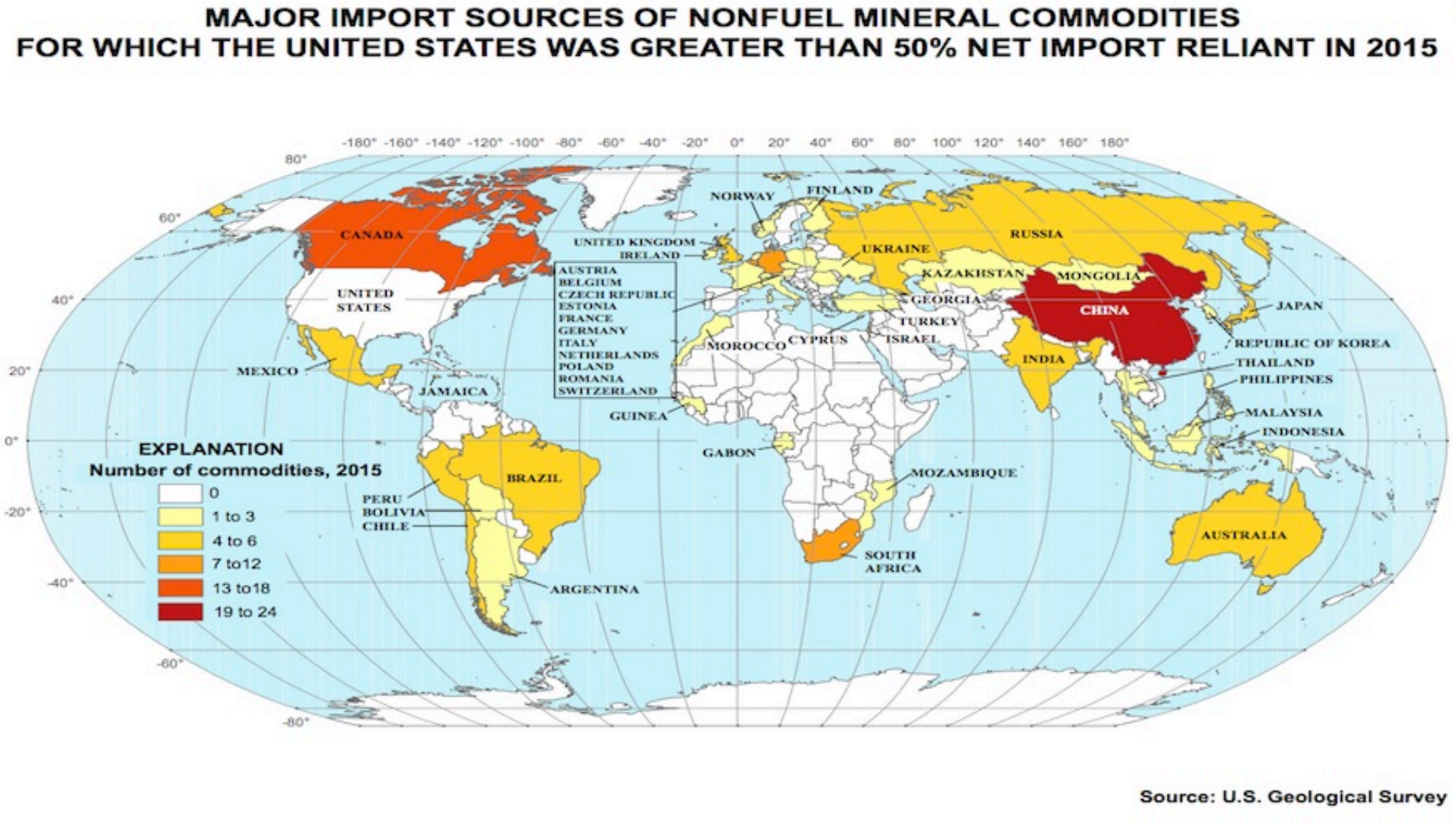
- **Amount used per year**: ~40,000 tons per year
- **Cost per pound:** $21.6/lbs —> ($47.5/kg Q3 2017)
- **Where we get it from:** “Rare Earth Element” Present in ore minerals; monazite and bastnäsite – China produces 80% of the worlds supply
- **How we get it:** Extracted by ion exchange and solvent 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 of 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?




https://en.wikipedia.org/wiki/File:Rareearth_production.svg

# 95% come from China. No US-plants



# 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