

Critical Minerals

The Economic and Public Policy Contexts

Rod Eggert

November 8, 2021

Critical Minerals Workshop
Oklahoma Geological Survey



COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT



Critical Materials Institute
AN ENERGY INNOVATION HUB

Starting Point:
What is a *Critical* Mineral?

Critical = indispensable, vital

Most of the 1st 83 elements in the periodic table are vital to someone

H Hydrogen																	He Helium
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium											13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Cesium	56 Ba Barium	57 - 71 La-Lu	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89 - 103 Ac-Lr	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

A narrower definition

Essential functionality (i.e., indispensable)

Difficult substitution

Supply-chain risks

Spices and vitamins of modern engineered materials



Sources:

<https://www.freeimages.com/photo/spices-1-1328086>

<https://www.freeimages.com/photo/vitamin-s-pill1-1259285>

Not copper – US output, more-diverse production

US list - draft 2021

- Gallium
- Niobium
- Cobalt
- Neodymium
- Ruthenium
- Rhodium
- Dysprosium
- Aluminum
- Fluorspar
- Platinum
- Iridium
- Praseodymium
- Cerium
- Lanthanum
- Bismuth
- Yttrium
- Antimony
- Tantalum
- Hafnium
- Tungsten
- Vanadium
- Tin
- Magnesium
- Germanium
- Palladium
- Titanium
- Zinc
- Graphite
- Chromium
- Arsenic
- Barite
- Indium
- Samarium
- Manganese
- Lithium
- Tellurium
- Nickel
- Beryllium
- Zirconium
-
- Cesium
- Erbium
- Europium
- Gadolinium
- Holmium
- Lutetium
- Rubidium
- Scandium
- Terbium
- Thulium
- Ytterbium

Note: In rank order from top to bottom and then left to right; elements starting with cesium were not rank ordered.

Source: Nassar and Fortier 2021 (USGS Open-File Report 2021-1045)

The Economic Context

Something important is at risk

Financial Times, October 22, 2020

Tesla's move into mining aimed at energising battery supply chain

March 30, 2021

The image shows the top portion of a web page from Mining Journal. The header is dark blue with the 'Mining Journal' logo in white. To the right of the logo is a globe icon and the word 'Edition' with a dropdown arrow. Further right are several navigation buttons: 'COVID-19' (highlighted in red), 'MJ Awards', 'Research', and 'Events'. To the right of these are social media icons for Twitter, LinkedIn, and Facebook. Below the header is a horizontal menu with six categories: 'EXPLORATION/DEVELOPMENT', 'FINANCE', 'COMMODITIES' (highlighted in yellow), 'VIEWPOINT', 'METS INVESTOR', and 'MINE RISK MANAGEMENT'. Below the menu is a large yellow banner containing the article title 'BMW announces Livent lithium supply deal' in bold white text. Underneath the title is a short paragraph of text in white, describing the deal between BMW and Livent.

Mining Journal Edition

COVID-19 MJ Awards Research Events

EXPLORATION/DEVELOPMENT FINANCE **COMMODITIES** VIEWPOINT METS INVESTOR MINE RISK MANAGEMENT

BMW announces Livent lithium supply deal

BMW says US chemicals company Livent will supply it with lithium from its operations in Argentina via a multi-year contract worth €285 million, with the undisclosed volume of material to be supplied directly to the automakers' battery cell manufacturers.

“What is ‘critical’ depends on
who you are, where you are,
and when you ask”

- Alex King

World, national, company, technology

Each element has its own story

Lack of supply chain diversity

Geopolitical risks

Co-production risks and opportunities

Technology risks

Entry barriers

Opaque markets

Etc.

The time dimension often is ignored

Short-term risks v.
Long-term availability

Consider the energy transitions

Critical minerals and the energy transitions

Broad context

- Demand
 - Will increase quickly and substantially for some materials, although at what rate and by how much is uncertain
- Supply
 - Is characterized by supply chains that often are fragmented, concentrated, small, opaque
 - May not grow ‘appropriately’ to meet growing demands (sufficiently, affordably, sustainably, responsibly)
- The Fear
 - Lack of ‘appropriate availability’ will become an obstacle to clean energy transitions

Electronic materials

e.g., solar applications, power electronics

Gallium, indium, selenium, silver, tellurium, tin



Magnets & motors

Wind turbines, EVs, other industrial and household uses

Selected rare earths



Energy storage & batteries

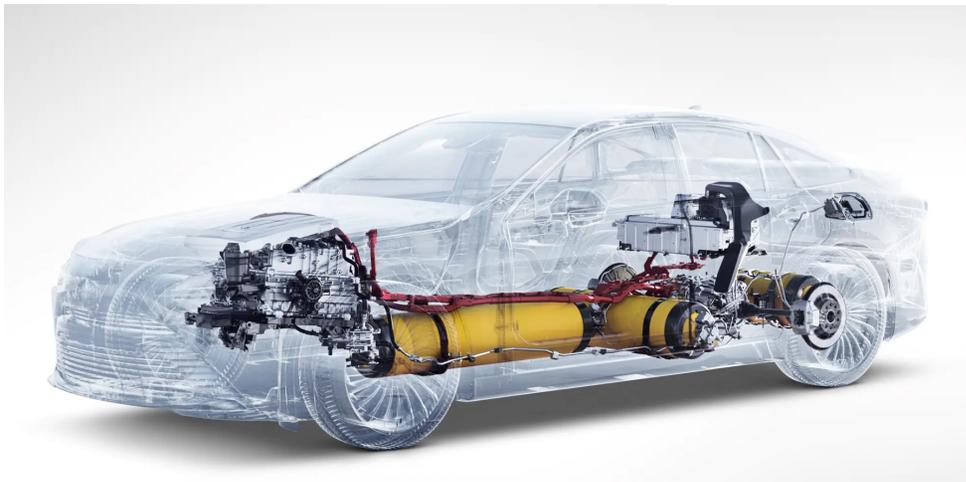
Lithium ion, solid-state lithium, sodium ion, flow, etc.

Lithium, nickel, cobalt, manganese, graphite, vanadium, sodium, lead, etc.



Fuel cells

Platinum-group elements,
selected rare earths



Nuclear

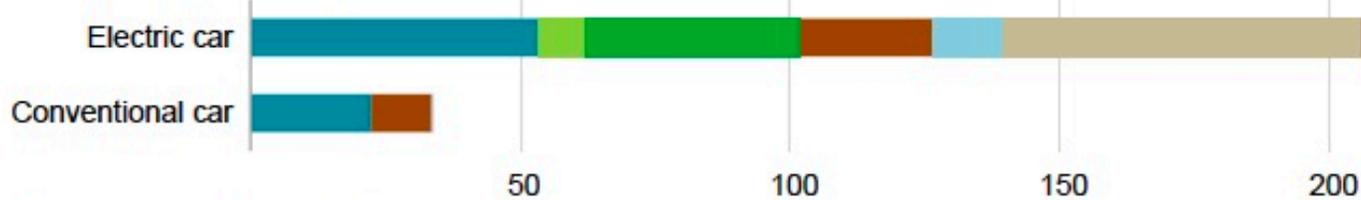
Cobalt, dysprosium,
gadolinium, hafnium,
indium



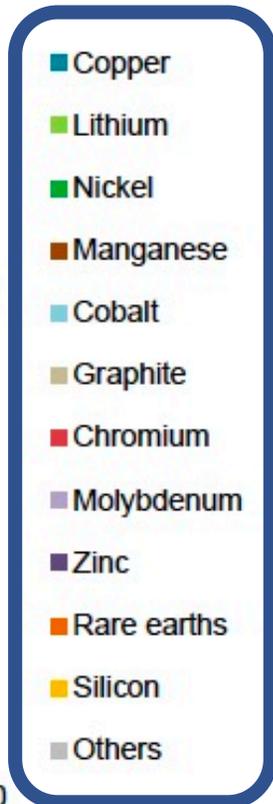
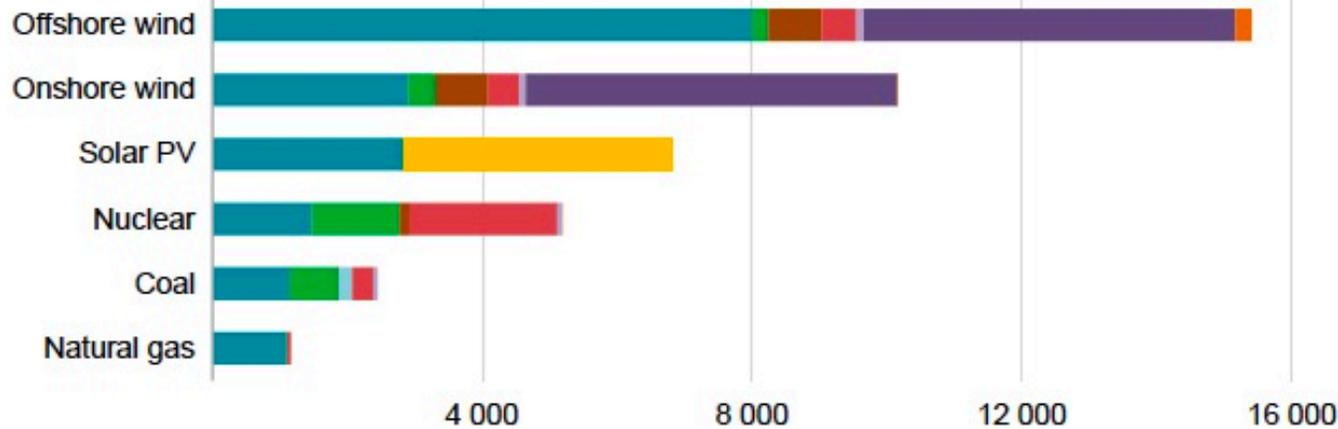
Demand for some mineral-based materials will increase significantly

Minerals used in selected clean energy technologies

Transport (kg/vehicle)



Power generation (kg/MW)

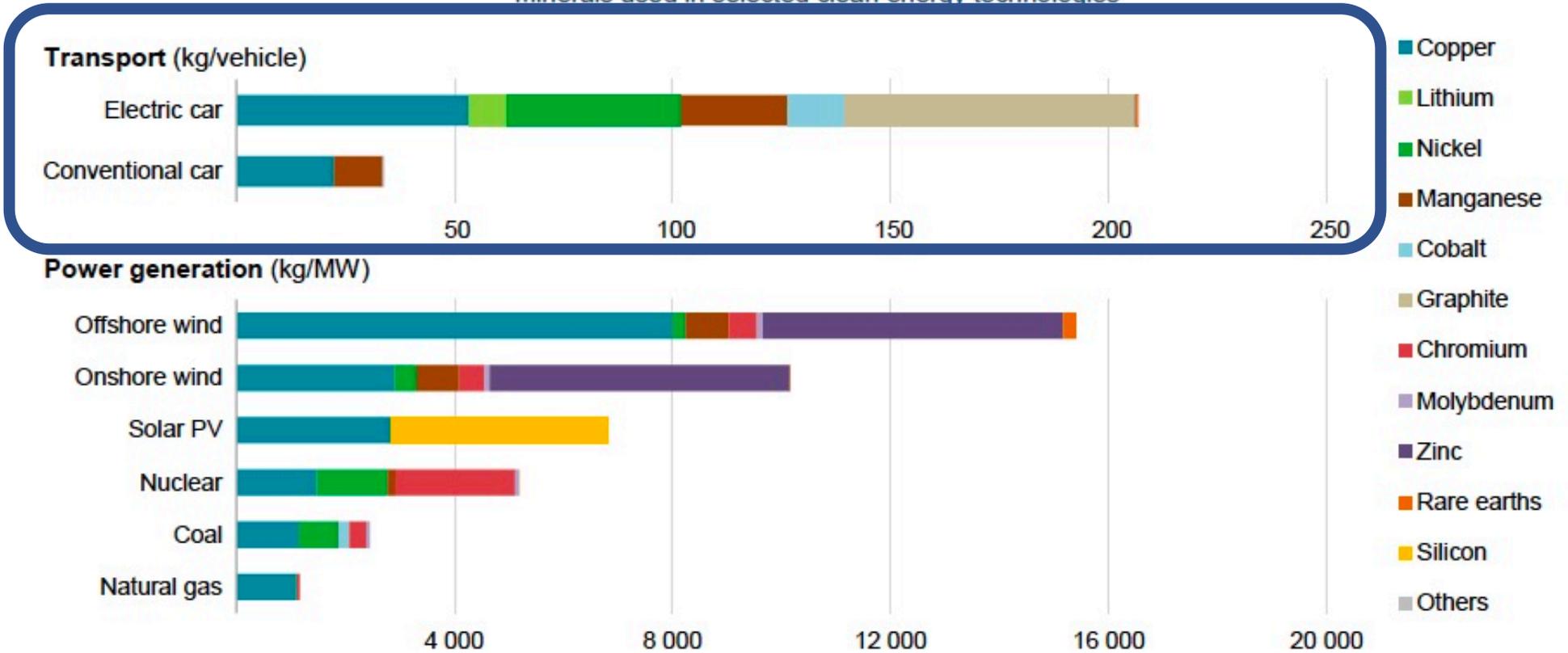


IEA. All rights reserved.

Notes: kg = kilogramme; MW = megawatt. Steel and aluminium not included. See Chapter 1 and Annex for details on the assumptions and methodologies.

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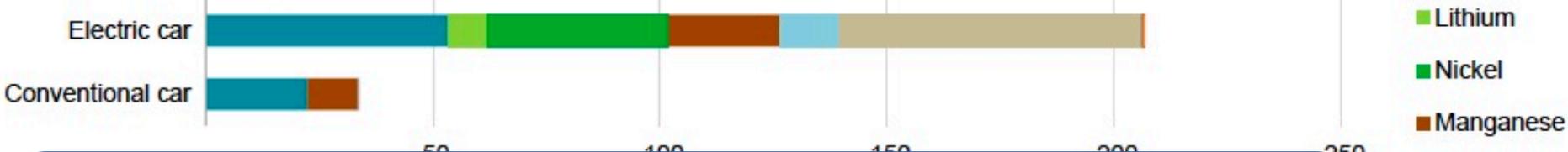
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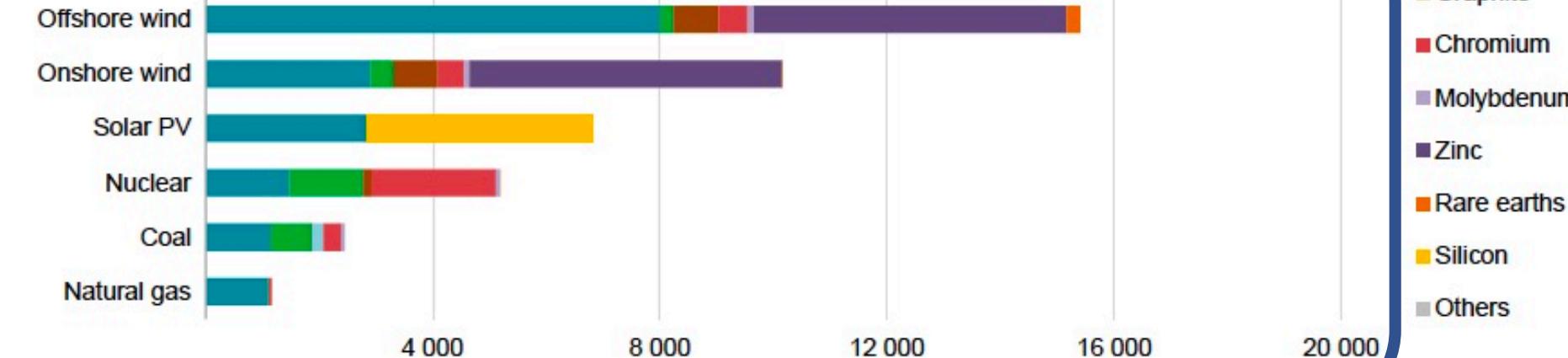
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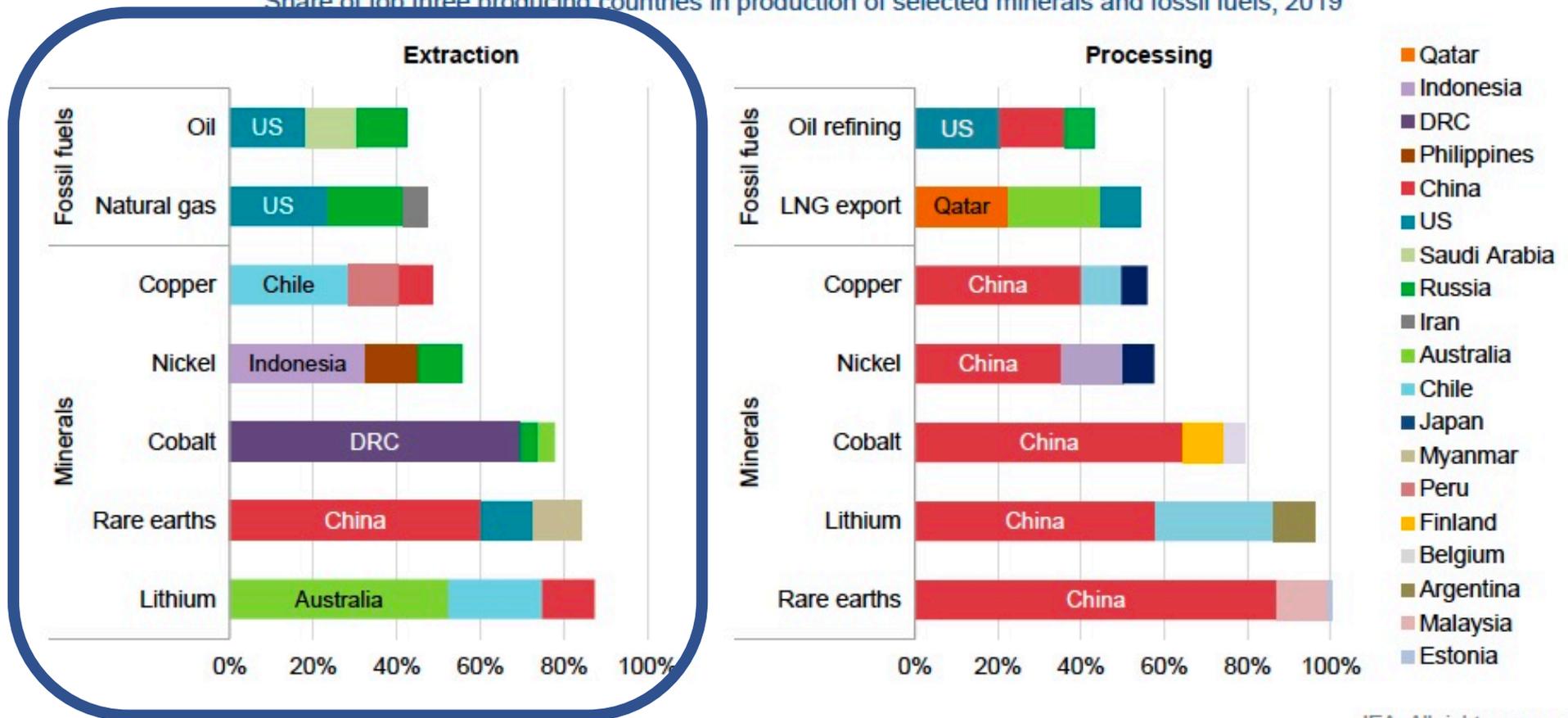
IEA. All rights reserved.

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It's about supply chains not just mining

Production of many energy transition minerals today is more geographically concentrated than that of oil or natural gas

Share of top three producing countries in production of selected minerals and fossil fuels, 2019



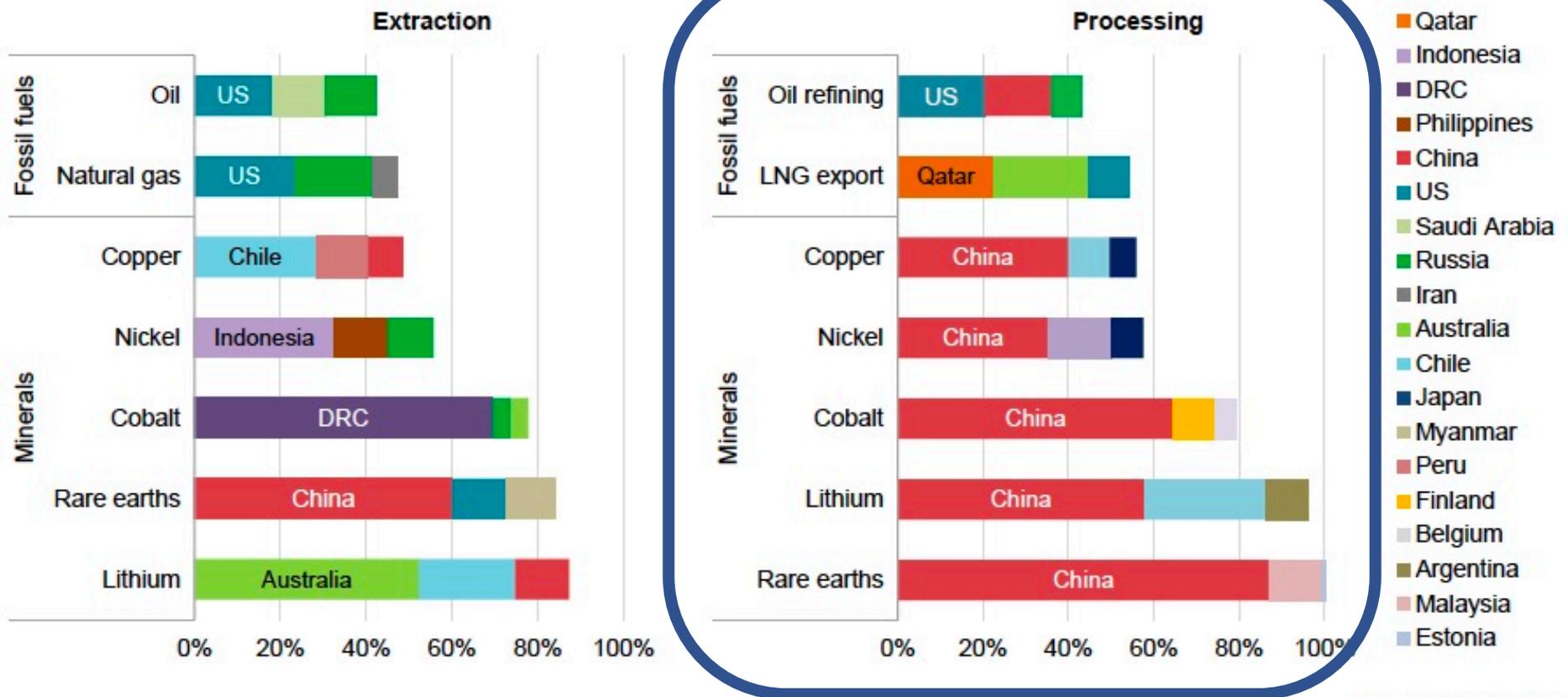
IEA. All rights reserved.

Notes: LNG = liquefied natural gas; US = United States. The values for copper processing are for refining operations.
Sources: IEA (2020a); USGS (2021), World Bureau of Metal Statistics (2020); Adamas Intelligence (2020).

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Source: [iea.org](https://www.iea.org)

The Public Policy Context

Or what to do?

March 28, 2021

**The
Economist**

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Weekly edition

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economics**

Mission critical

Governments identify minerals needed for economic and national security

Obtaining them is another matter

One month into the Biden administration

THE WHITE HOUSE



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BRIEFING ROOM

Executive Order on America's Supply Chains

FEBRUARY 24, 2021 • PRESIDENTIAL ACTIONS

But also an issue in the Trump administration

U.S. Presidential Executive Order 13953

**Executive Order on Addressing the Threat to the
Domestic Supply Chain from Reliance on Critical
Minerals from Foreign Adversaries**

 ECONOMY & JOBS

Issued on: September 30, 2020

Financial Times, August 31, 2020

EU sounds alarm on critical raw materials shortages

Transition to a low-carbon economy and pandemic disruption exacerbate Europe's dependence on problematic partners

What needs to be accomplished?

What role for government?

- Produce more
 - Enhance and diversify primary production
- Waste less
 - Improve manufacturing efficiency
 - Enhance re-use and recycling
- Use less
 - Develop substitute materials or technologies

Possible policy approaches

- ‘Neoliberal’: rely on private initiative, focus government activities on market failures
 - Distortions to international trade
 - Education & workforce development
 - Information and strategic analysis
 - Research (science & technology policy)
- ‘Industrial policy’: achieve change sooner
 - Stockpiles
 - Government offtake agreements/domestic content requirements
 - Subsidies, tax incentives
 - Loans/loan guarantees
 - Equity co-financing

Framework for U.S. Policy, 2019

6 calls to action – mostly ‘neoliberal’

- Advance transformational research, development and deployment across critical mineral chains
- Strengthen America’s critical mineral supply chains and defense industrial base
- Enhance international trade and cooperation related to critical minerals
- Improve understanding of domestic critical resources
- Improve access to domestic critical mineral resources on federal lands and reduce federal permitting timeframes
- Grow the American critical minerals workforce

More
industrial
policy -
Gaining
momentum
since Great
Financial Crisis,
accelerated by
pandemic

**BUILDING RESILIENT
SUPPLY CHAINS,
REVITALIZING AMERICAN
MANUFACTURING, AND
FOSTERING BROAD-BASED
GROWTH**

100-Day Reviews under
Executive Order 14017

June 2021

A Report by
The White House

Including Reviews by
Department of Commerce
Department of Energy
Department of Defense
Department of Health and Human Services



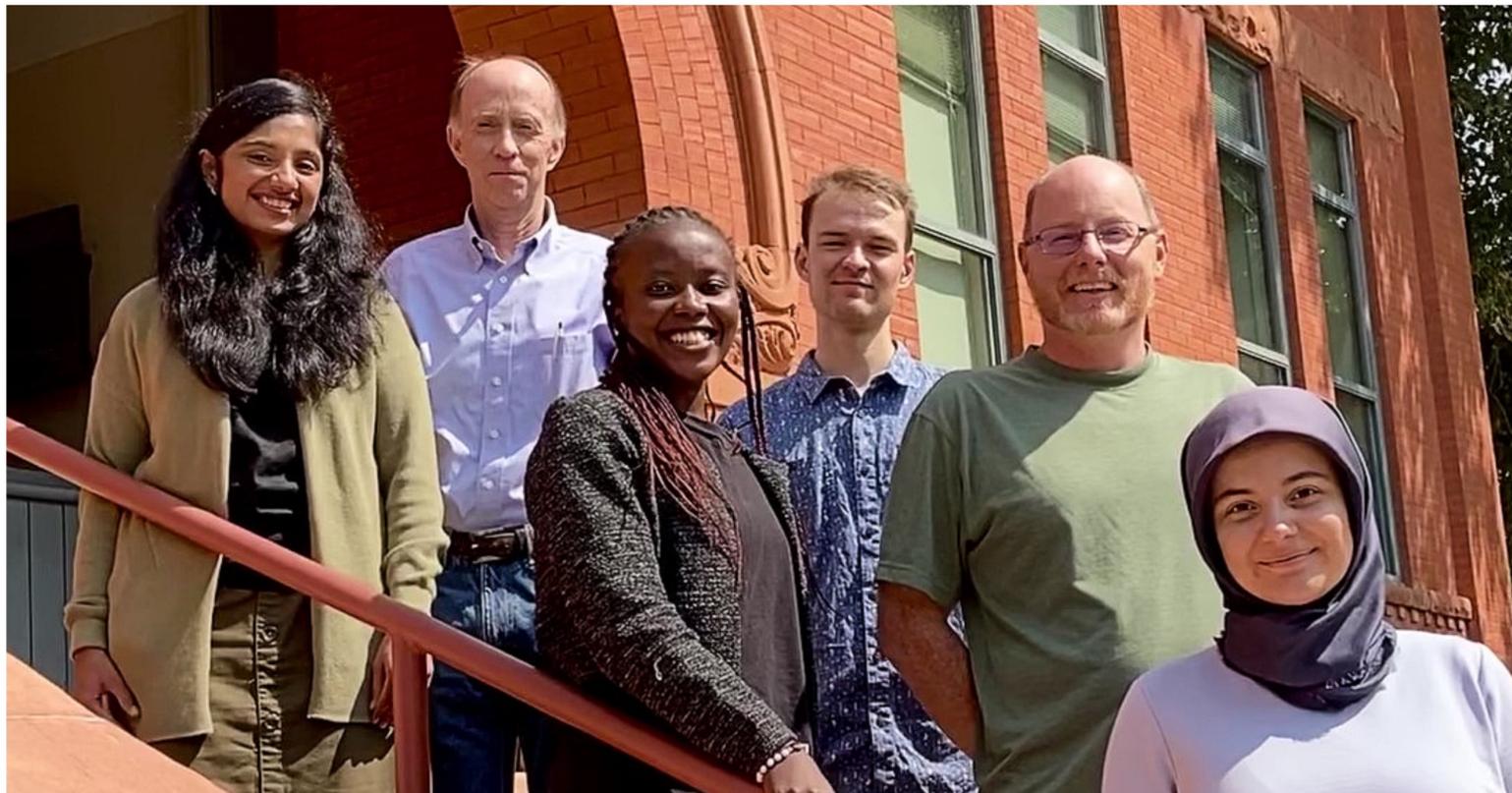
THE WHITE HOUSE
WASHINGTON

Summing up

- **Critical minerals**
 - Essential functionality, difficult substitution, supply chain risks
- **Economic context**
 - Something important is at risk, situational
 - The time dimension often is ignored
- **Public policy context**
 - How to produce more, waste less, use less
 - What is the appropriate mix of private and public activities?
 - What are the social goals not being met by market activities?



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Fall 2021, Eggert Research Group

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