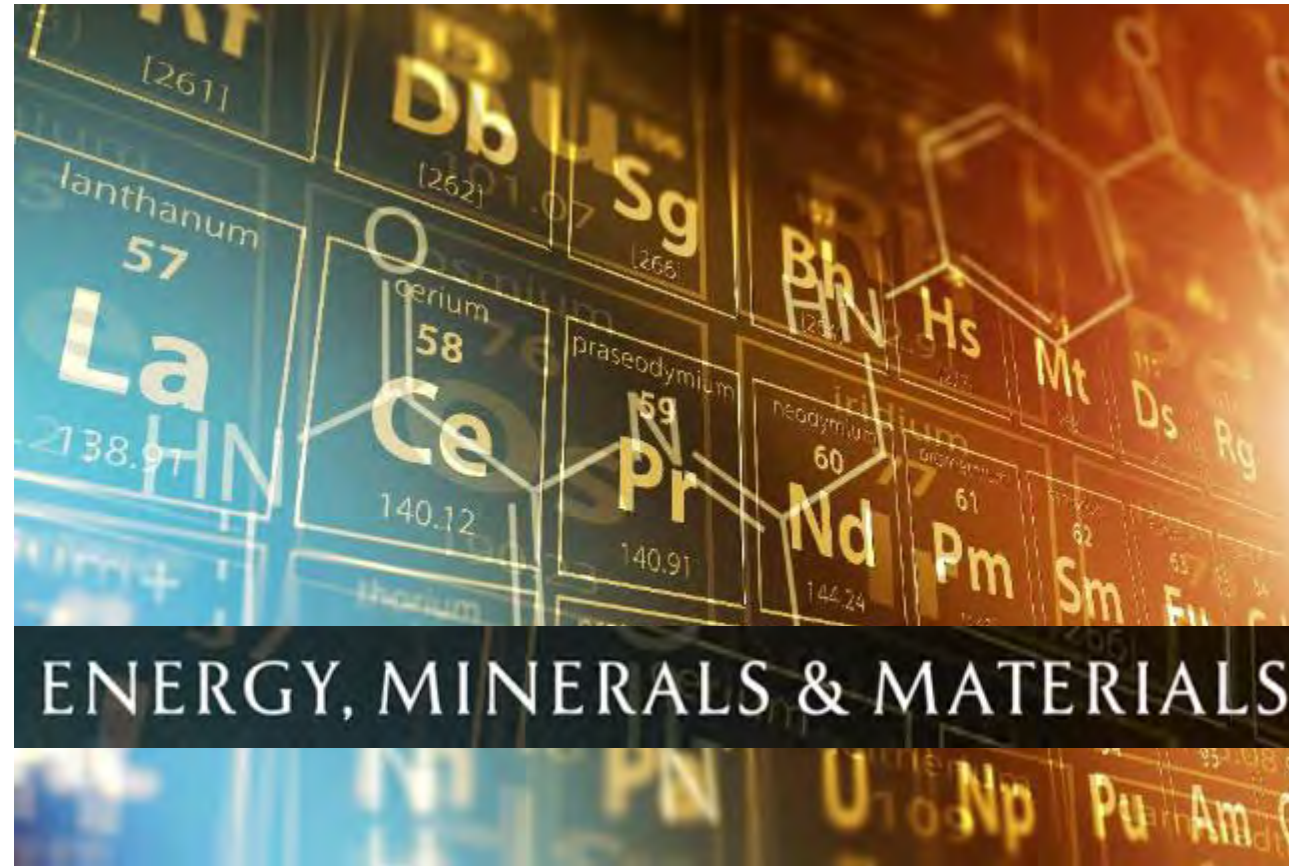


# **Understanding the Minerals Wild West**



***Michelle Michot Foss, Ph.D.***  
***IEEJ/APERC, April 25-26 and 27, 2023, Tokyo***



<https://www.bakerinstitute.org/global-minerals-production-dashboard>

<https://www.bakerinstitute.org/global-minerals-trade-dashboard>

# Notes on Compilation

Several slides represent **Work in Progress** and are marked as such. These are sensitive – we request no outside circulation without permission.



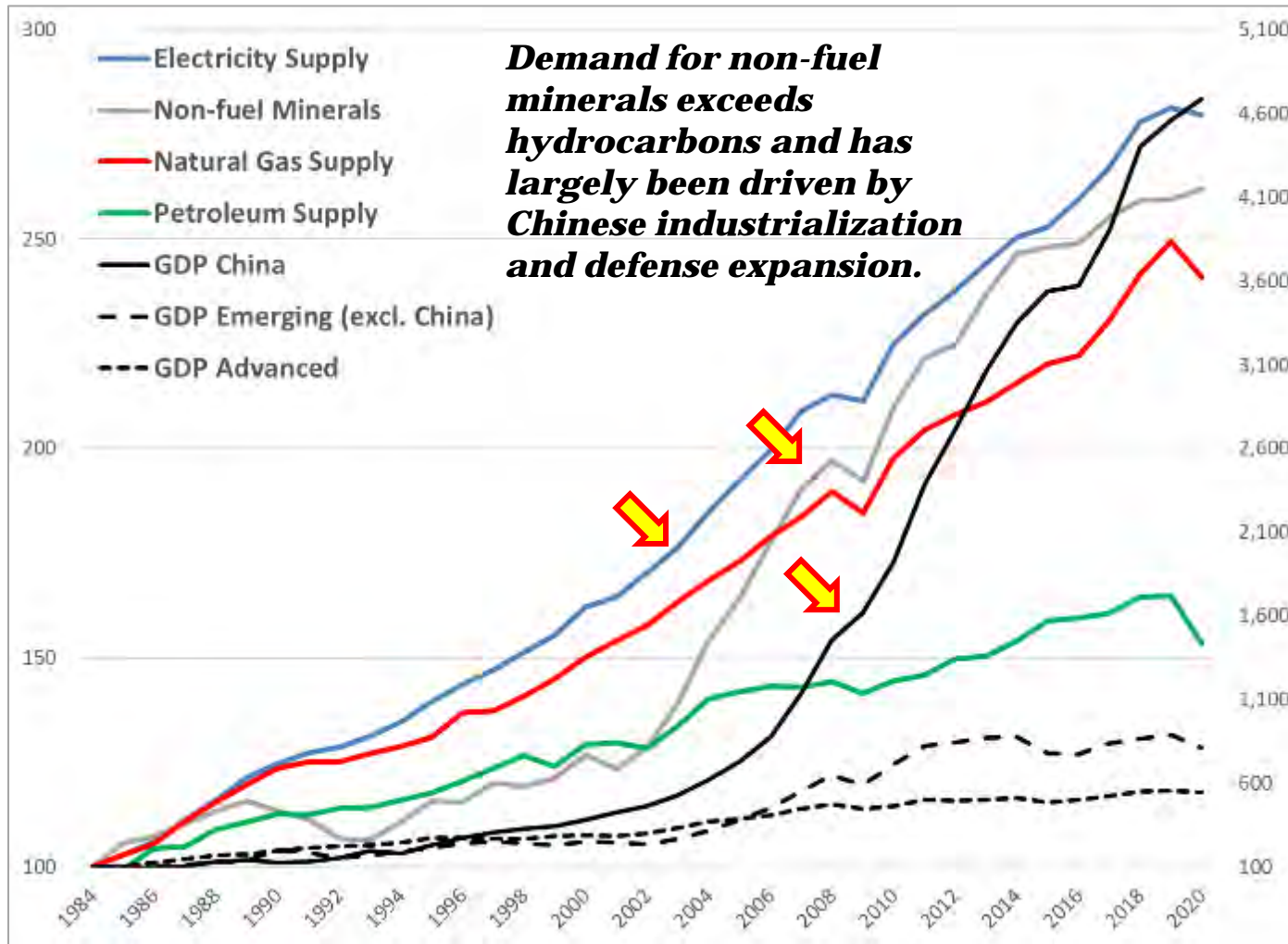


[https://en.wikipedia.org/wiki/It%27s\\_a\\_Mad,\\_Mad,\\_Mad,\\_Mad\\_World](https://en.wikipedia.org/wiki/It%27s_a_Mad,_Mad,_Mad,_Mad_World)

*Backdrop*

**It's a mad, mad, mad, mad world.**

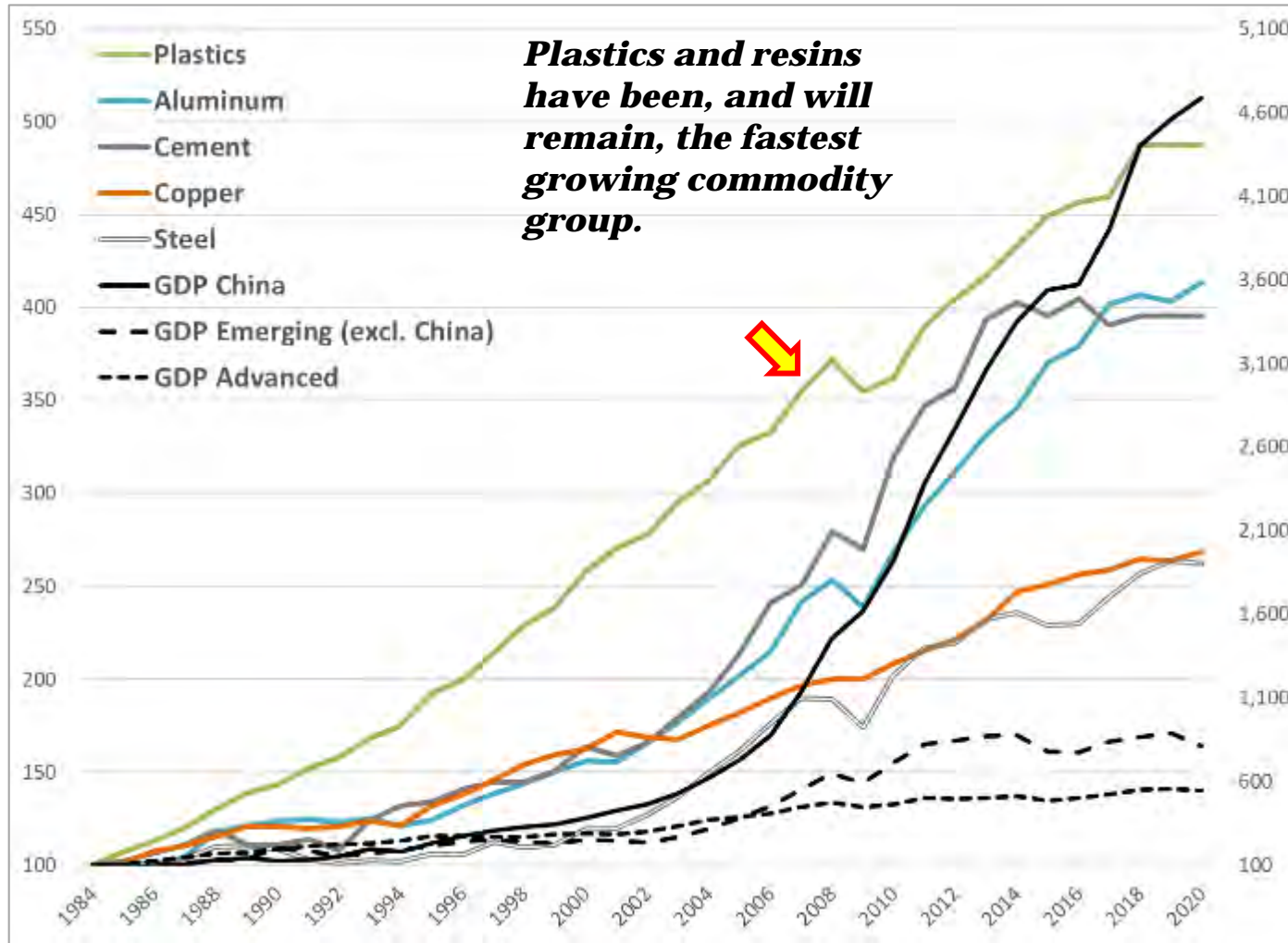
# Where We Stand, I



M. Michot Foss using BP, WMC, IMF indexed to 1984. NOTE – GDP on right axis.

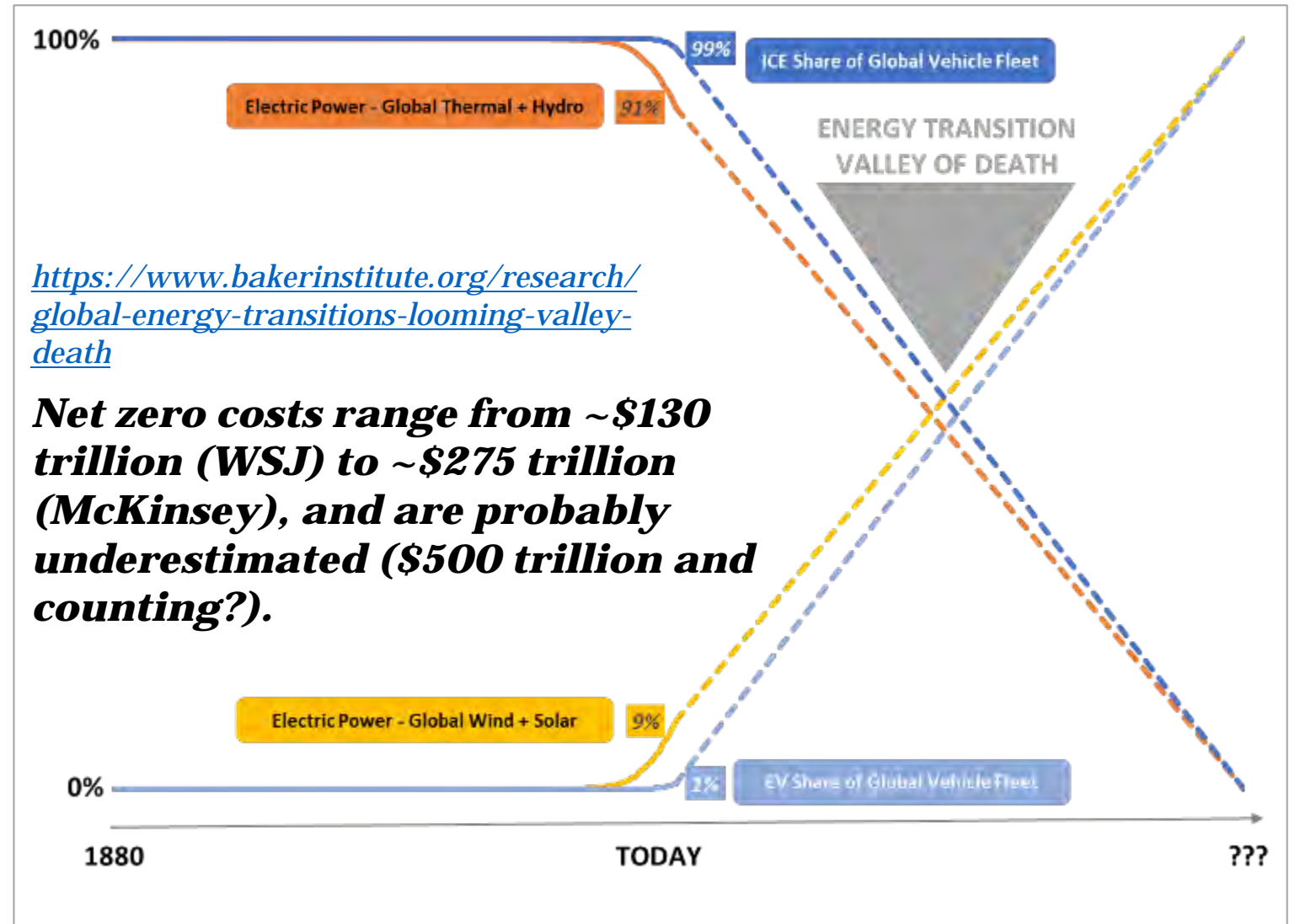
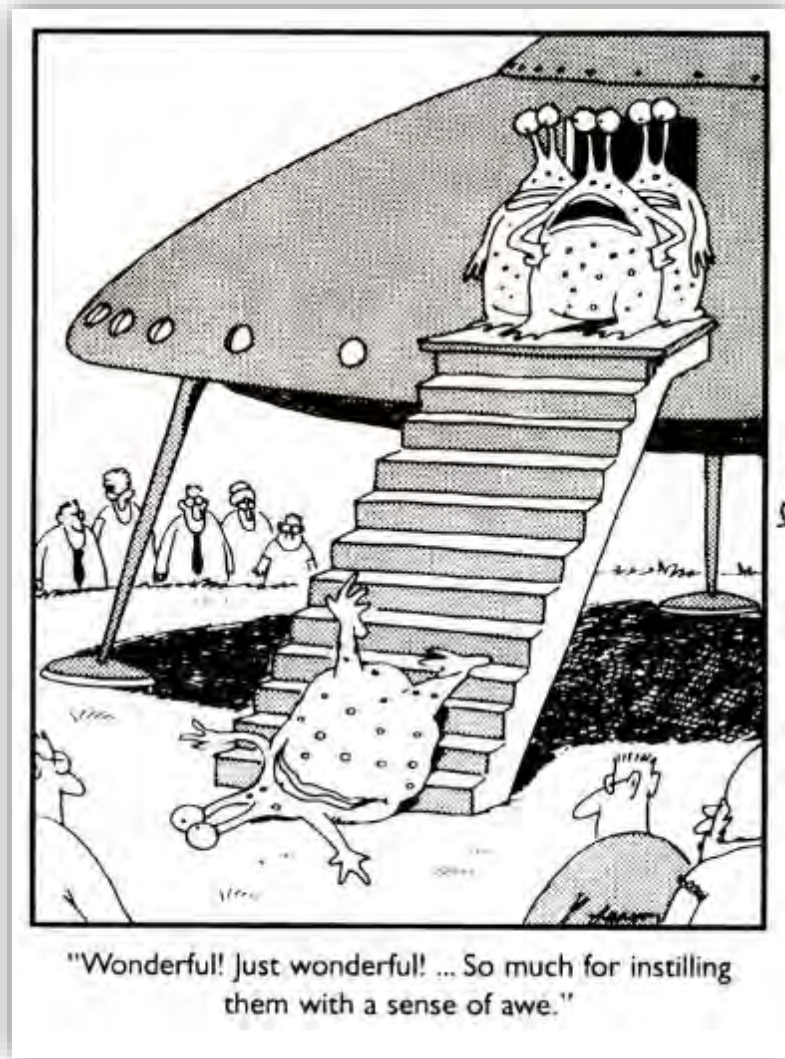


# Where We Stand, II



M. Michot Foss using BP, WMC, IMF indexed to 1984. NOTE – GDP on right axis.

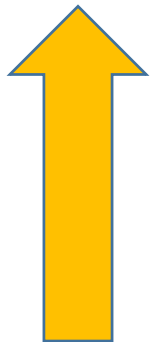
# The Energy Transition(s) Valley(s) of Death



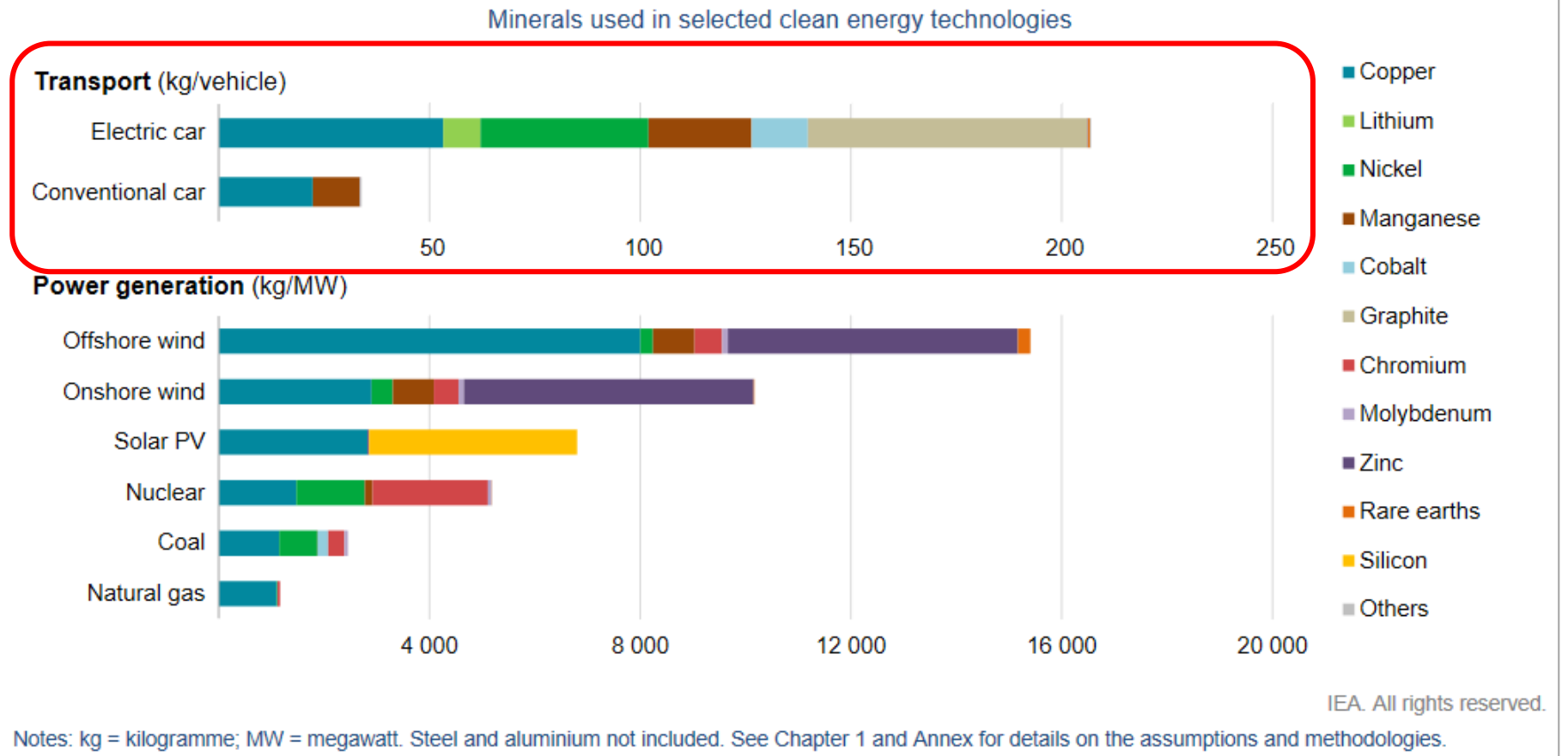
# The Bet: We can trade off energy density with minerals/materials intensity and come out ahead.

**Lower  
Energy  
Density**

**Higher  
Materials  
Intensity**



The rapid deployment of clean energy technologies as part of energy transitions implies a significant increase in demand for minerals





# Upside Down ~~Renewables~~

Energy Source	Number of Generators	Number of Generation Locations	Generation per Location ('000 MWh)	Share of U.S. Power Generation	Median Footprint
Natural Gas	6,020 thermal units	1,793	906	40.5%	310
Nuclear	96 reactors	55	14,361	19.7%	5
Coal	668 thermal units	244	3,170	19.3%	1,203
Wind (USGS)	78,008 turbines	1,422	238	8.4%	11,907
Hydro	4,014 dams	153	1,865	7.1%	647
Solar PV (grid)	Unknown	4,599	19	2.1%	1,974
Wood		332	109	0.9%	47,048
Geothermal		170	93	0.4%	46
Solar CSP		18	174	0.1%	1,319

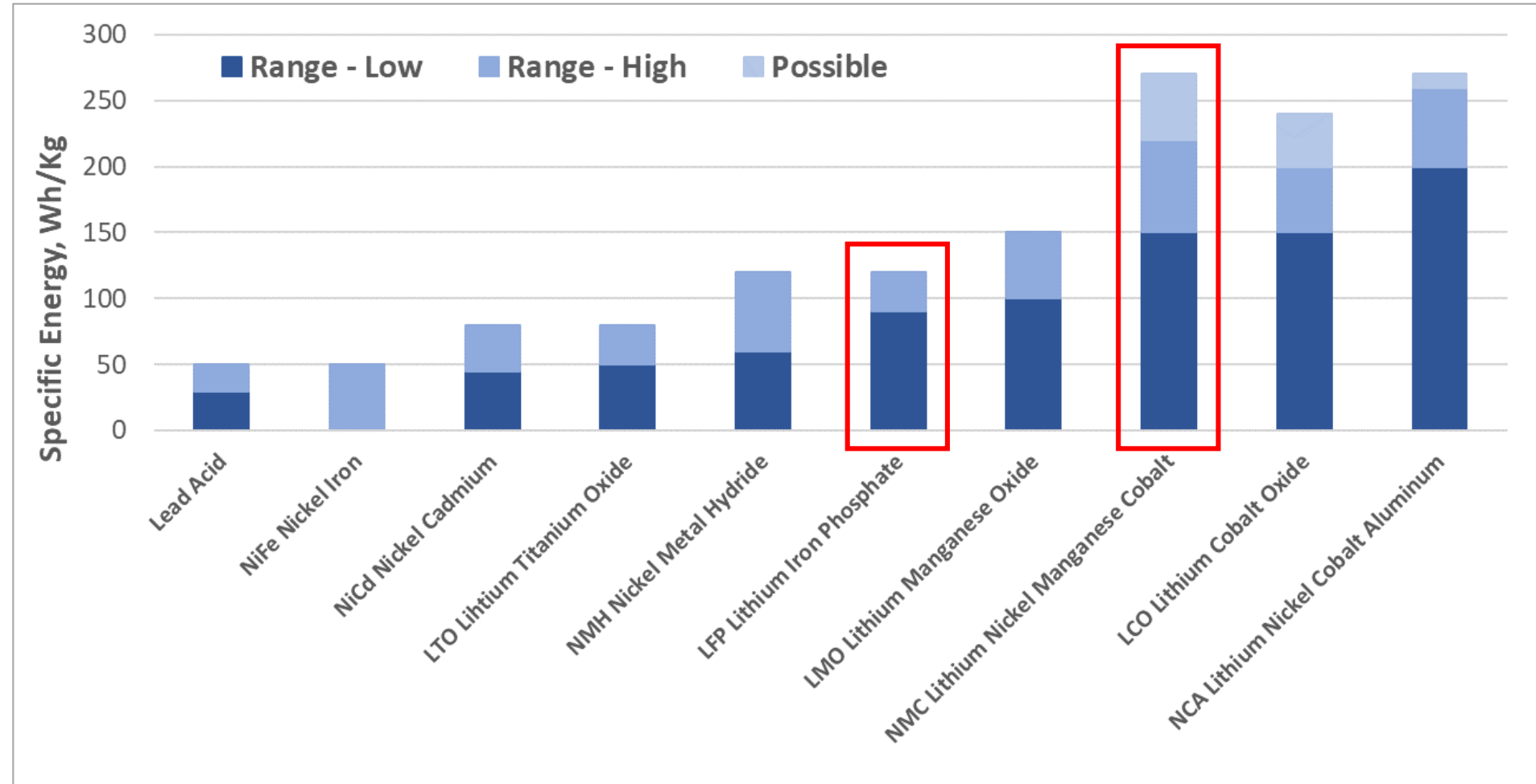
*At least two analyses put footprint – land use from sourcing to installation and refueling – of wind, solar, wood (biomass) as exceeding fossil fuels and nuclear. NOTE – uranium nuclear fuel is almost entirely sourced abroad. Data from US EIA and USGS wind database, compiled by author. See:*

<https://docs.wind-watch.org/US-footprints-Strata-2017.pdf>

<https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0270155#sec009%20>.

# Commercial Battery Chemistries

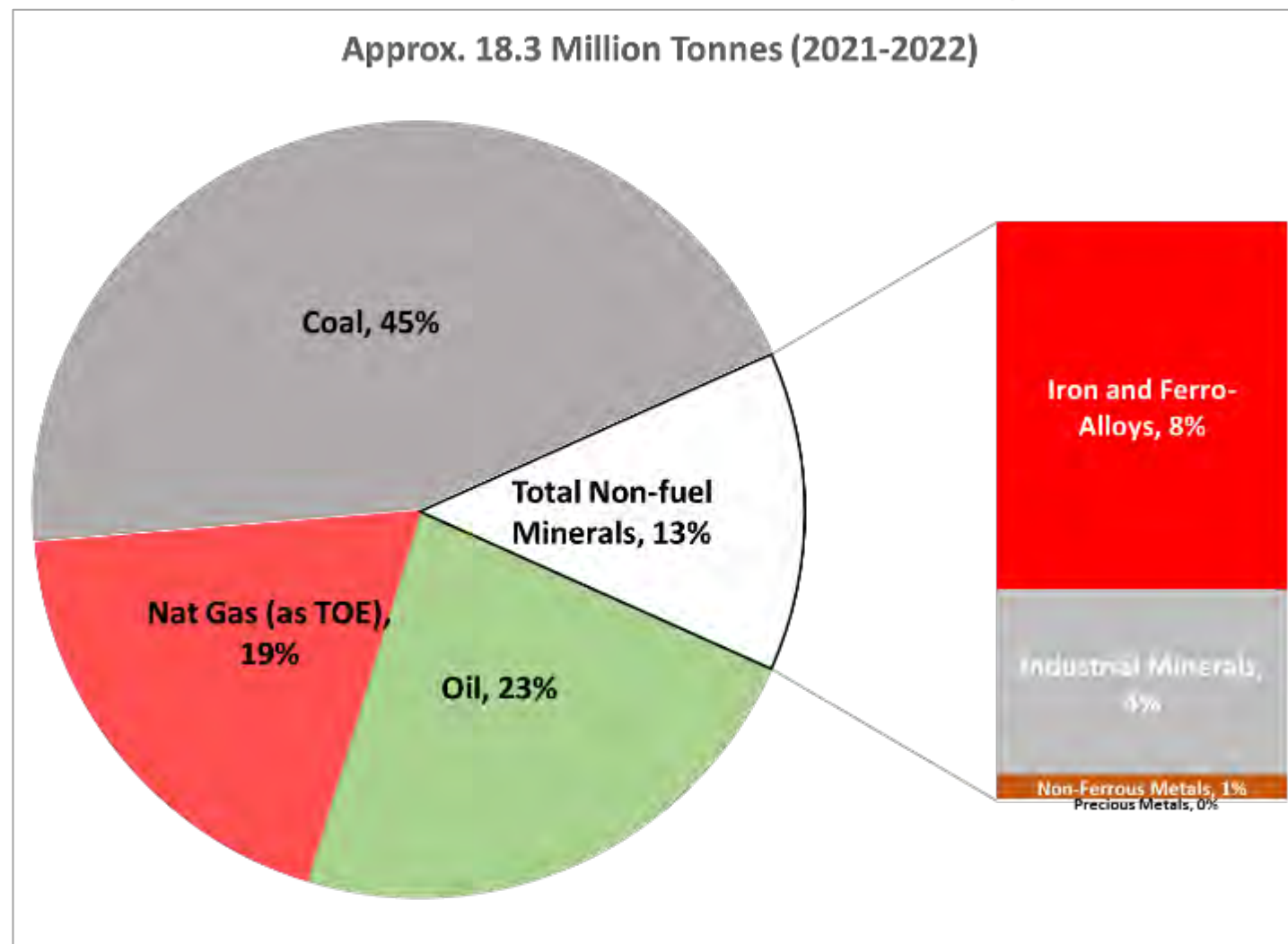
**Gasoline =  
~12,500 Wh/Kg**



*Author using various sources including Sherritt International and Battery University*

# Fuel and Non-fuel Minerals Output

- In “net zero” scenarios both the energy equivalent **AND** intrinsic energy storage attributes of fossil fuels must be replaced.
- Battery metals and materials **ONLY** provide energy storage.
- Energy must be provided from other sources in the equivalent of fossil fuels commitments **IF** fossil fuels are to be displaced.
- **ALL** non-fuel minerals will be needed, not just battery metals and materials.
- See WMD for nf minerals classifications.

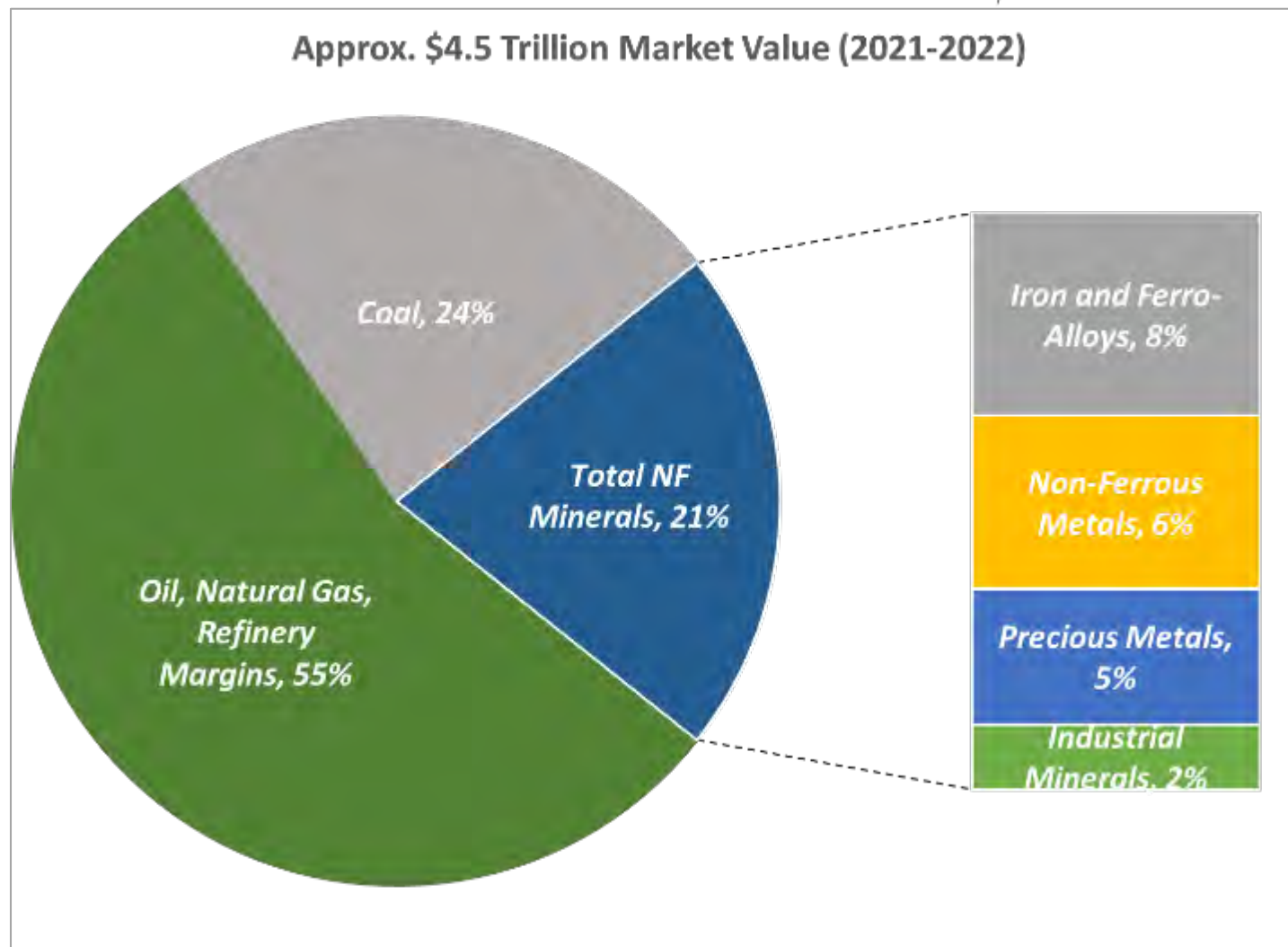


*MM Foss using BP, WMD, EIA and other. TOE is tonnes of oil equivalent. Work in progress. Note that ~20% of oil and gas is directed to materials. Excludes bauxite.*



# Fuel and Non-fuel Minerals Market Values

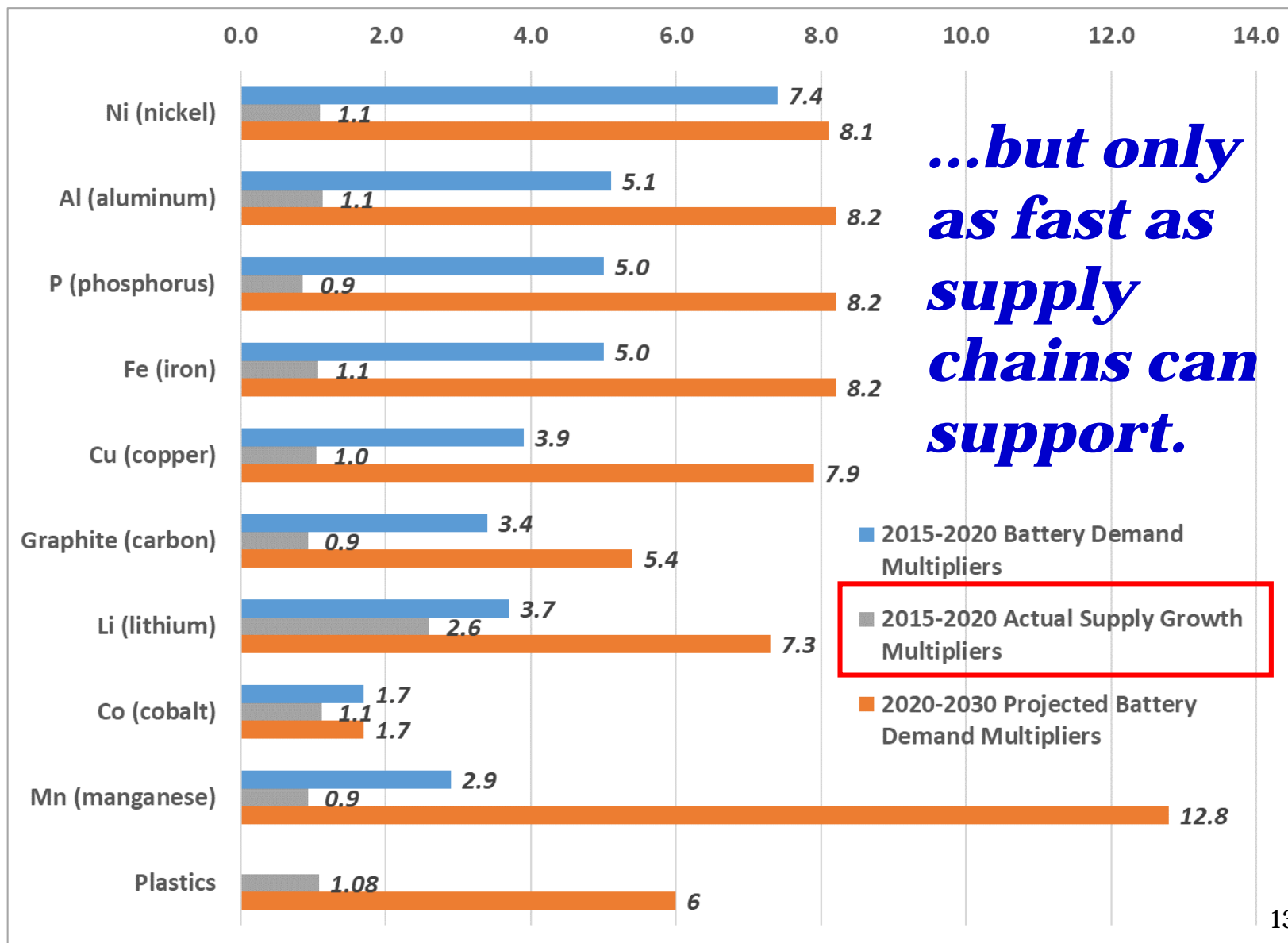
- Much of mining industry cash flow derives from...**COAL!**
- The total value of all mined non-fuel minerals is **21%** of the total market value of fuel and non-fuel commodities together, based on 2021 production and 2022 market values of ~\$3.5 trillion.
- Miners and sovereigns aspire to replace oil in value, but...
- ...hydrocarbons remain vital for ongoing energy and materials needs, and...
- ...there is no effective producer association (OPEC) for nf minerals (past attempts failed).



*MM Foss using BP, WMD, EIA and other. Work in progress. Note that market values are for crude oil, natural gas and average refining margins. Excludes bauxite.*

# All of the growth fit to print...

- Demand multipliers reflect growth **ONLY** from EV production.
- BNEF expects **passenger EVs to grow from 53% to 67% of battery market in 2030**, with other EVs at 24% and non-transport use (incl. stationary storage) 9%.
- Metals for batteries could “crowd out” metals for other uses.

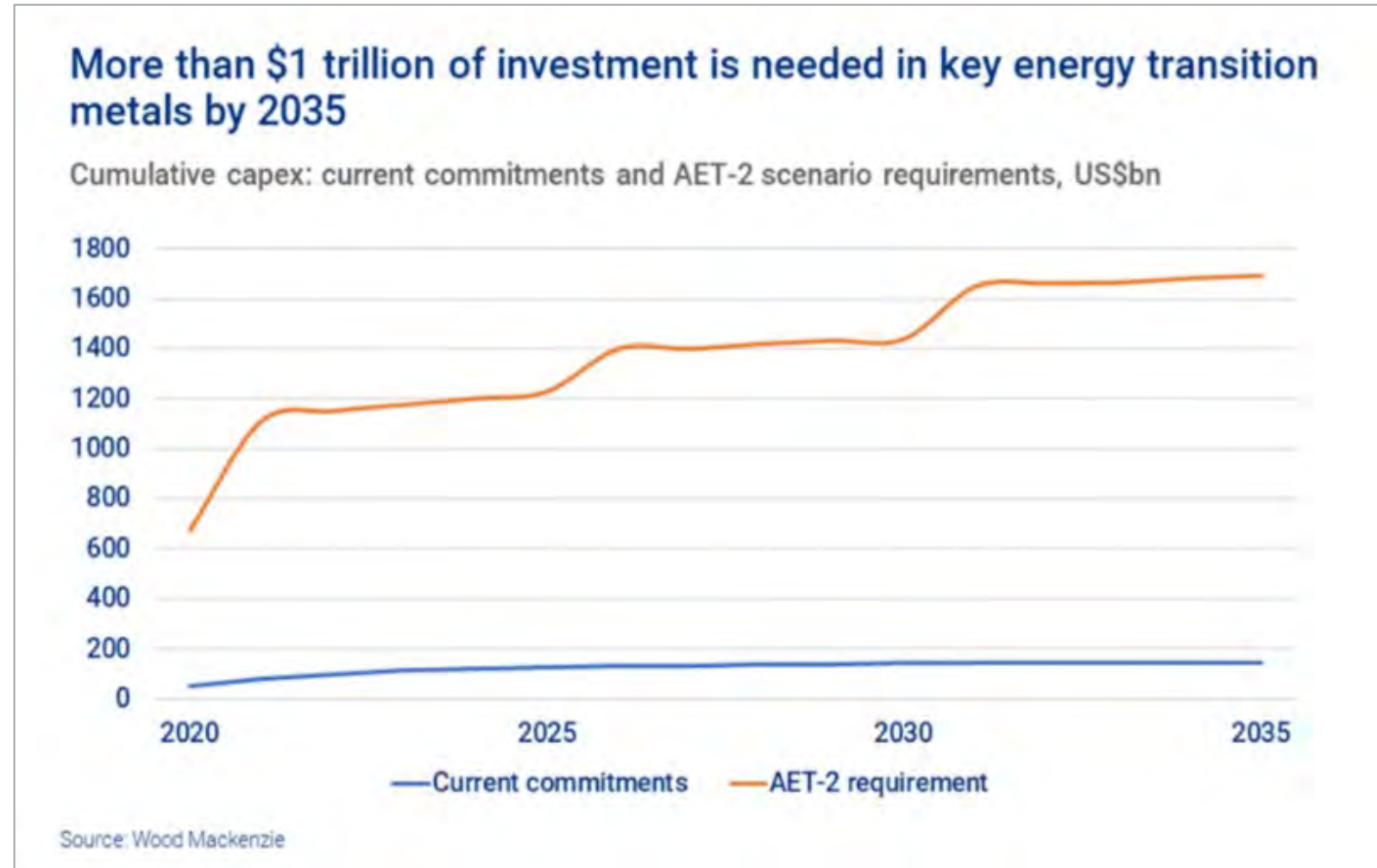


*...but only as fast as supply chains can support.*

2015-2020 actuals (total minerals supply) based on CES baseline. Demand multipliers from BNEF. Plastics estimated by author.

# Minerals Investment Context

- “These heady growth scenarios will **double** the aluminum, copper and nickel market over the next 20 years. For cobalt and lithium, supply will have to rise **five-fold** over the same period.”
- Investors funneled only **\$600 billion** to increasing lithium, cobalt, nickel, aluminum and copper production from 2005 to 2020.
- For an accelerated energy transition, Wood Mackenzie predicts nearly **three times more investment, nearly \$1.7 trillion**, is required to increase supplies of these metals by 2035.
- **This level of investment has yet to materialize and there are serious concerns that it ever will.**

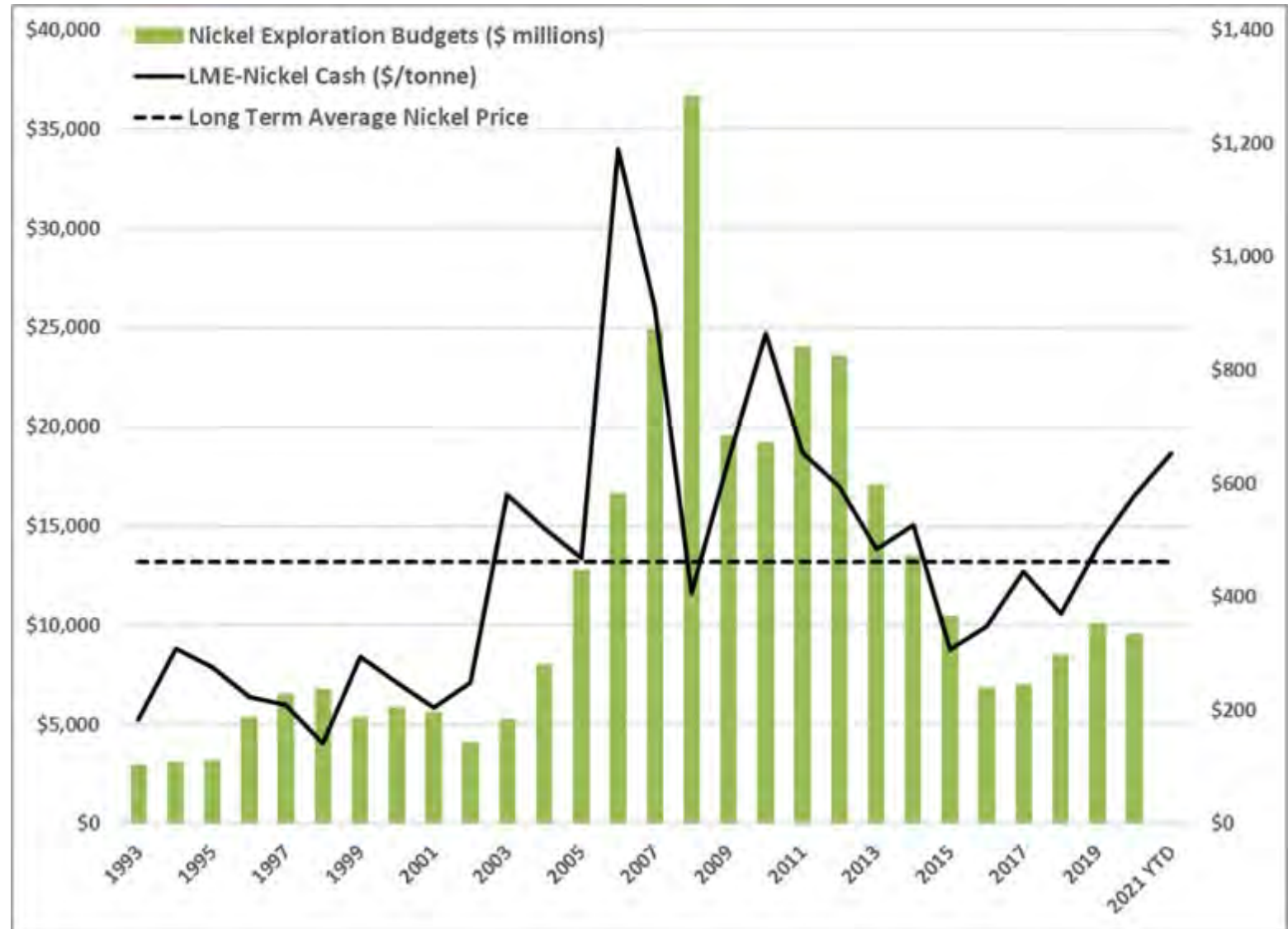


<https://www.woodmac.com/news/opinion/faster-decarbonisation-and-mining-a-crisis-of-confidence-or-capital/>



# Follow the Money: Nickel Example

***Exploration budgets are contingent on risk-weighted expected returns, sensitive to price.***



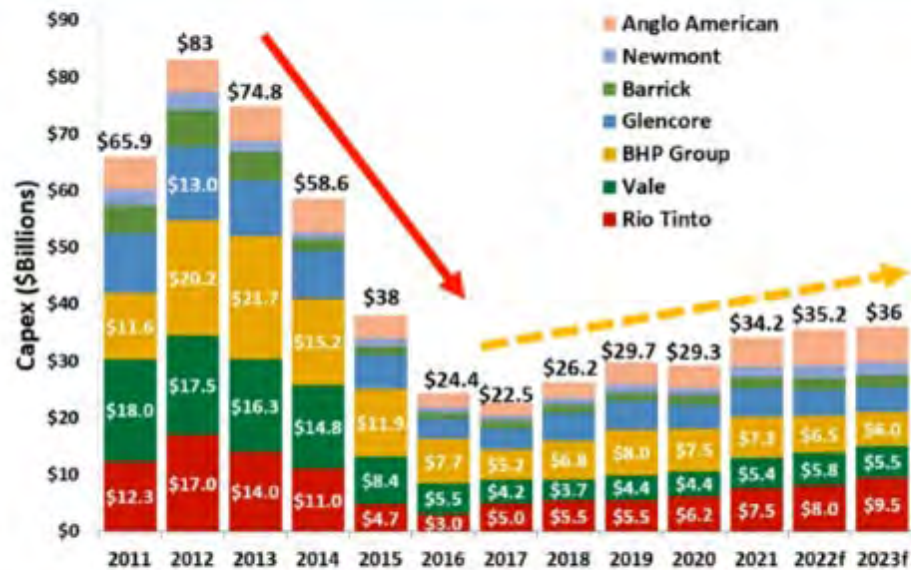
Author analysis based on SPG, accessed via license.

# An undercapitalized industry struggles to spend...

## Major Mining Company Capital Expenditures

Capex Spending by Year 2011 – 2023

Sponsored By:



- Capex up 3% in 2022 and 2% in 2023
- 52% increase in spending 2017-2021
- These 7 companies account for about 10% of the active projects

### Macro Investment Themes



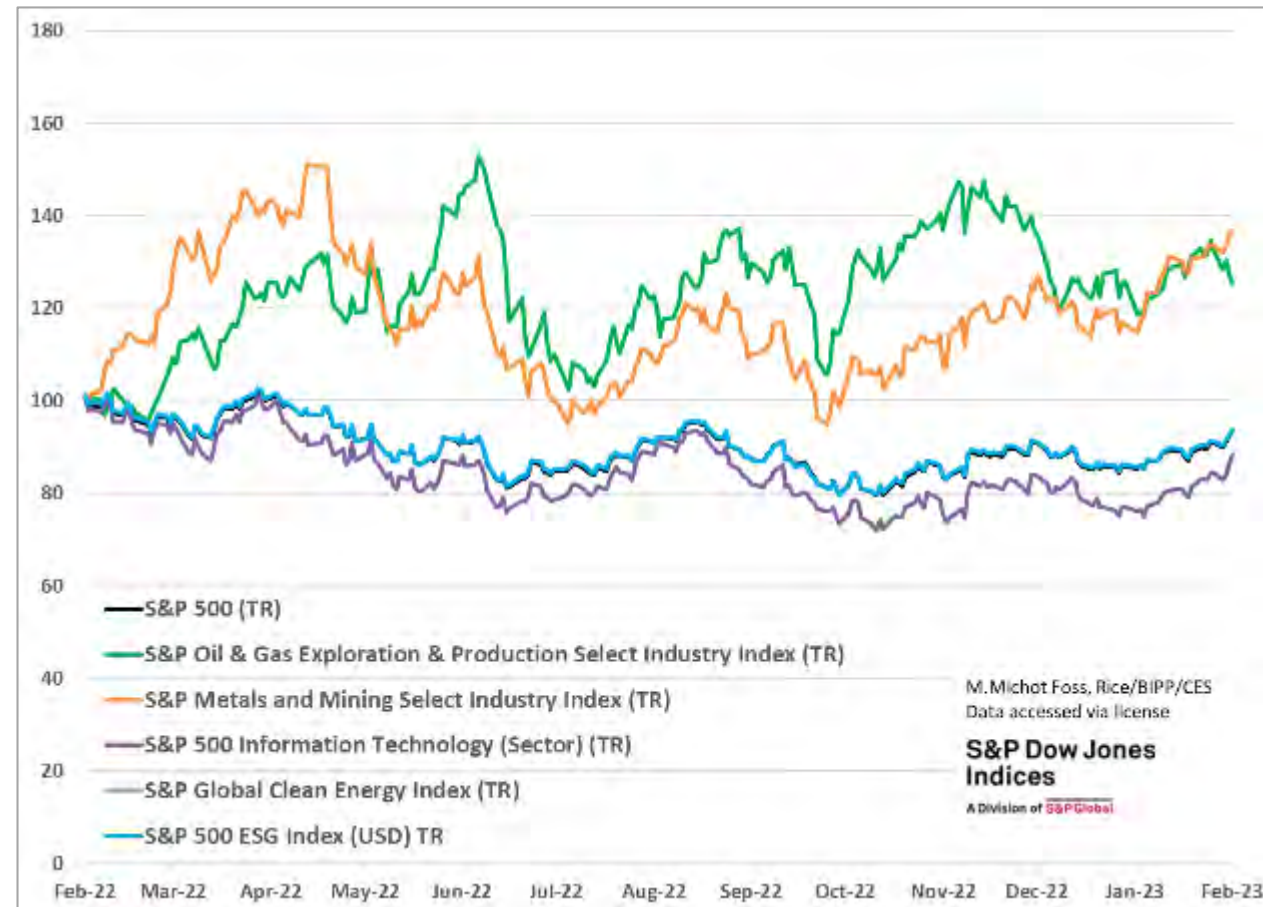
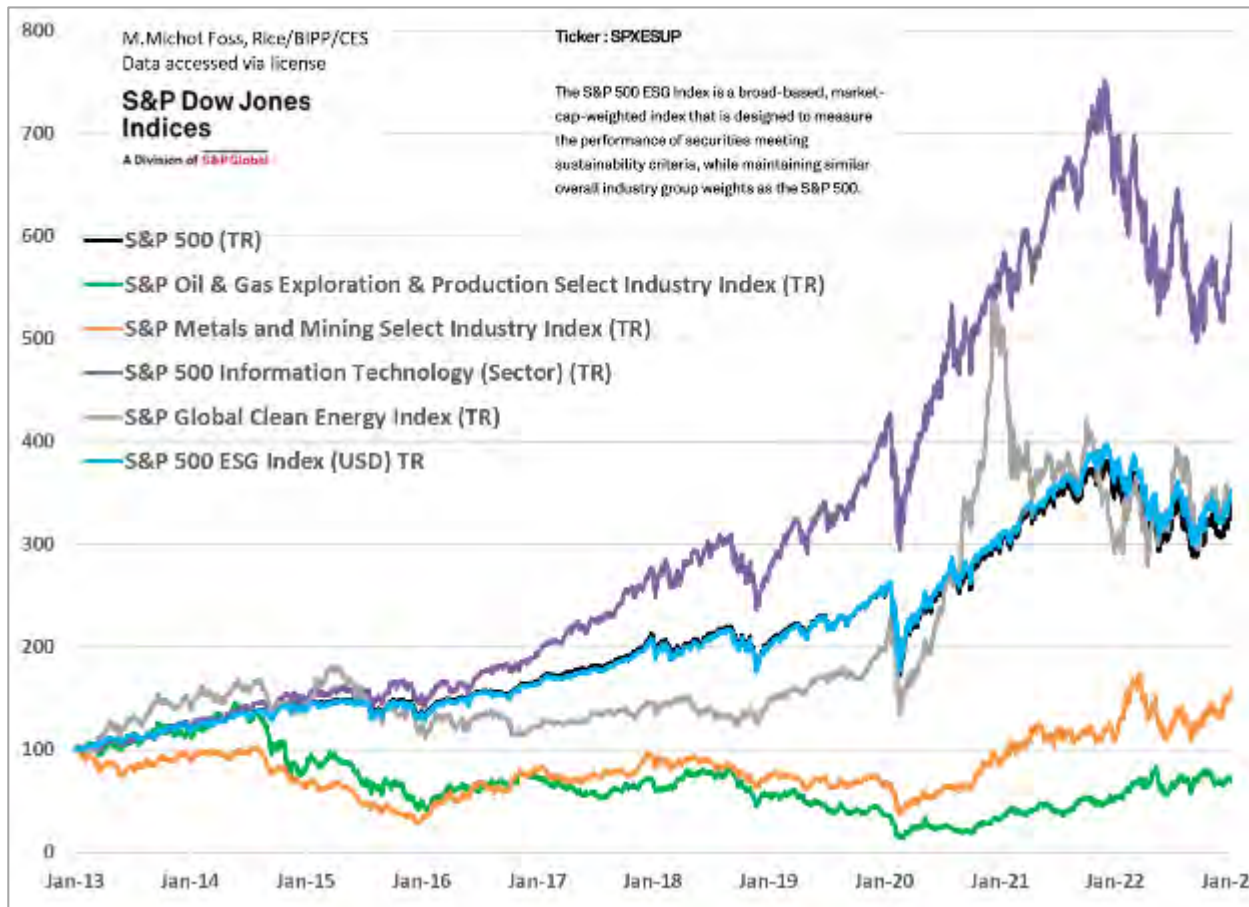
- Strategic production capex / increase in underground investment.
- Mine expansions over grassroots.
- Expect scaled investments into energy transition metals & minerals.
- With focus on cost management/margin improvement investments.

# ...while investors struggle to stick with the (net zero, ESG) program.

*\*The Revenge of the Old Economy*

## 10-Year Total Return

## 1-Year Total Return



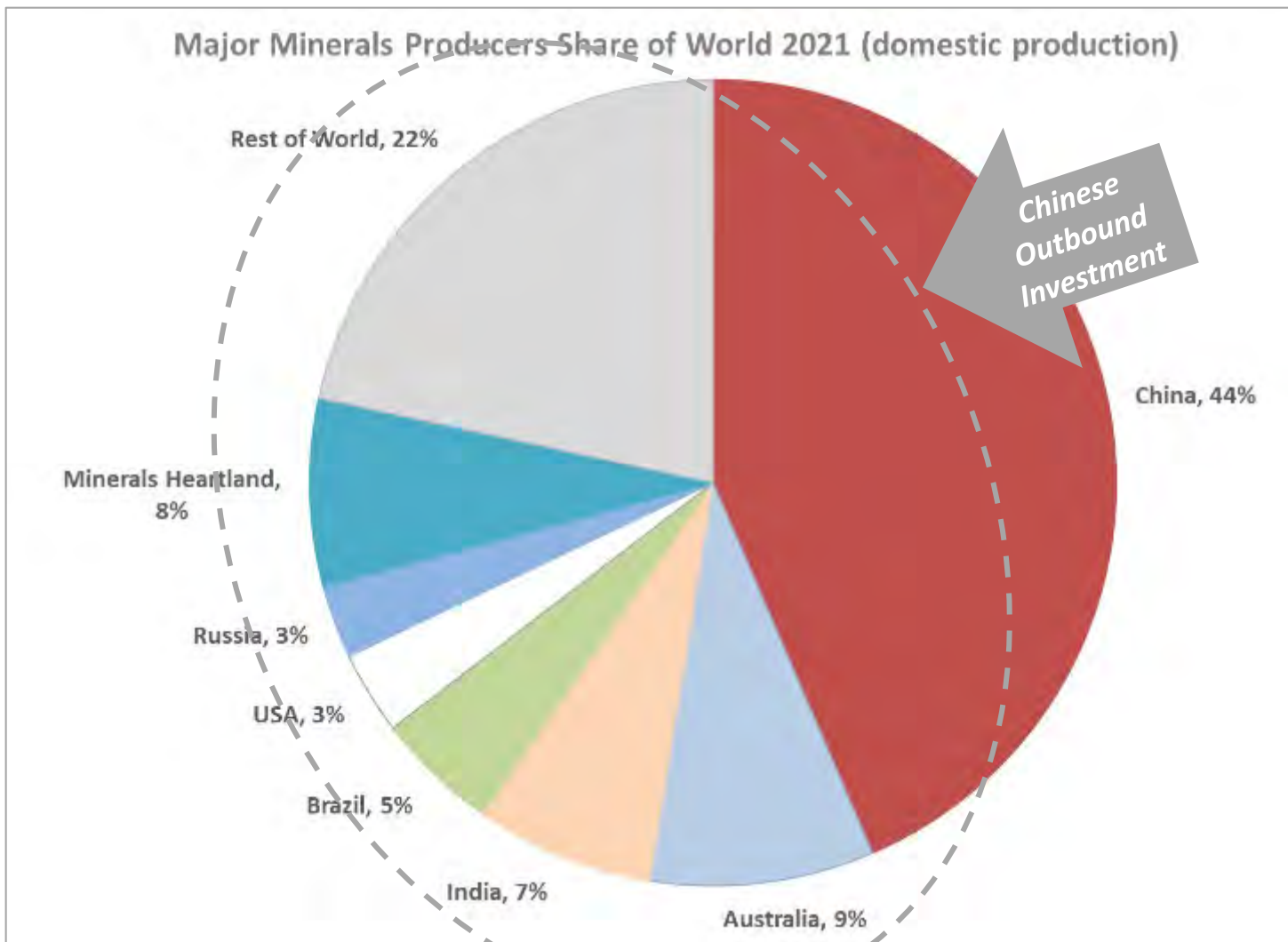
*\*Jeff Currie, for FT, Oct 21, 2021 <https://www.ft.com/content/c7732d53-2e34-4fde-b5fb-6f45f114111f>*



*What's in a name?*

# **Critical Minerals/Mining Industry Challenges**

# Who's on first?



## China controls:

- More than 90% each of gallium and germanium;
- **80% of rare earth materials with new SOE;**
- 70% of graphite/graphene;
- 60% of lithium;
- Nearly 60% of vanadium;
- 41% of indium;
- 36% of cobalt;
- 50% or more of copper refining with comparable shares for other metals;
- International trade (copper, lithium, nickel and other);
- ~60% of wind turbines manufacturing;
- ~70% of solar PV output;
- **~70-80% or more (90+% of announced) of large format battery manufacturing capacity (NMC, LFP).**

*Chart based on USGS as compiled by CES, Minerals Heartland is Africa, Middle East, Central Asia; China shares based on FP Analytics and other sources as compiled by CES*

# How Battery Mfg Capacity Stacks Up

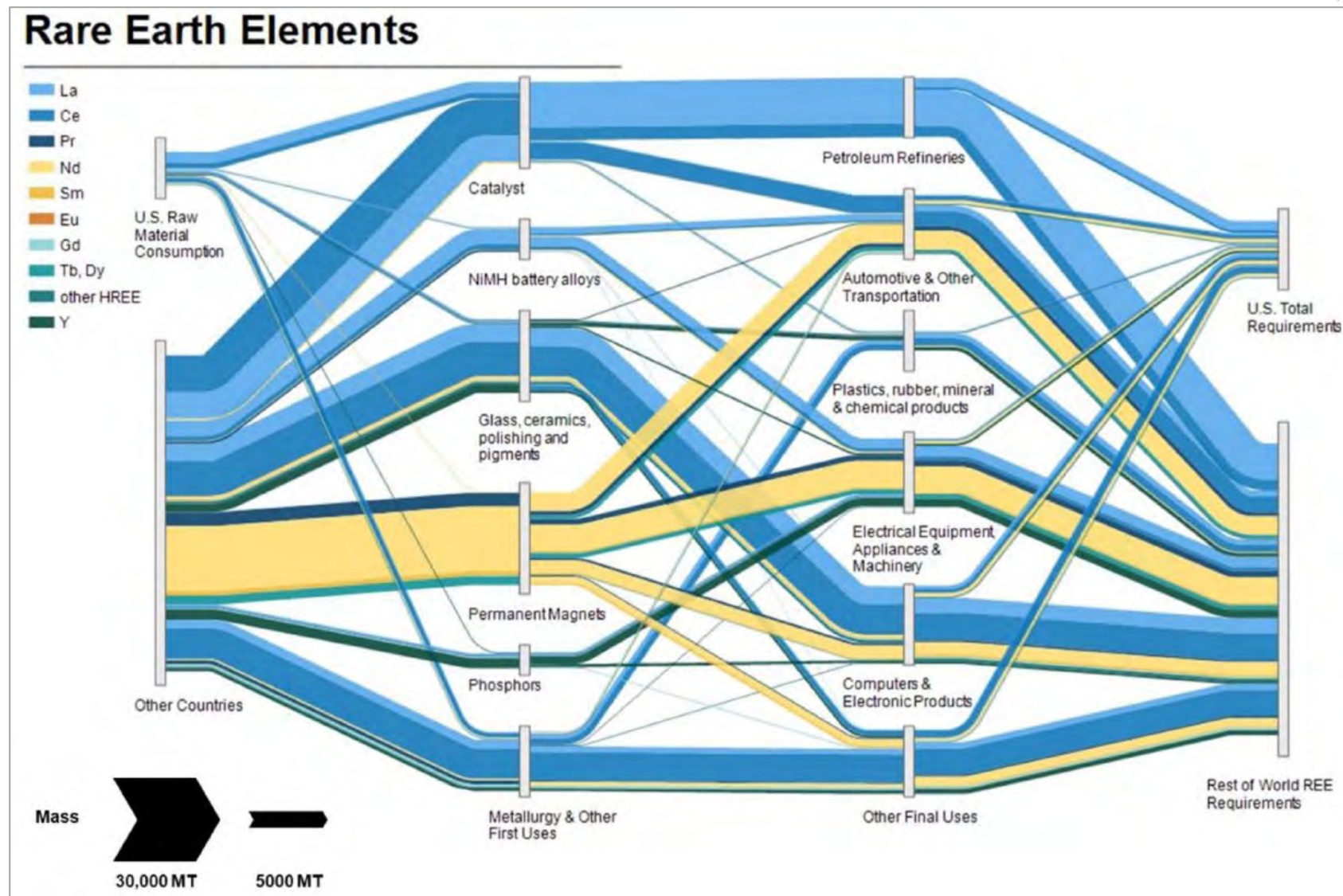
	World	China	China Share of World
<b>NMC Chemistry (where known)</b>			
Fully Commissioned	368	257	70%
Under Construction	299	252	84%
Announced	502	502	100%
<b>% NMC of World, China Total Battery Chemistries (based on Table 2)</b>			
Fully Commissioned	55%	50%	
Under Construction	31%	30%	
Announced	27%	63%	
<b>LFP Chemistry (where known)</b>			
Fully Commissioned	89	85	96%
Under Construction	164	164	100%
Announced	77	74	97%
<b>% LFP of World, China Total Battery Chemistries (based on Table 2)</b>			
Fully Commissioned	13%	16%	
Under Construction	17%	20%	
Announced	4%	9%	

Source: Compiled by authors using BNEF inventory, accessed via license.

<https://www.bakerinstitute.org/sites/default/files/2022-04/import/research-paper-nickel-041122.pdf>

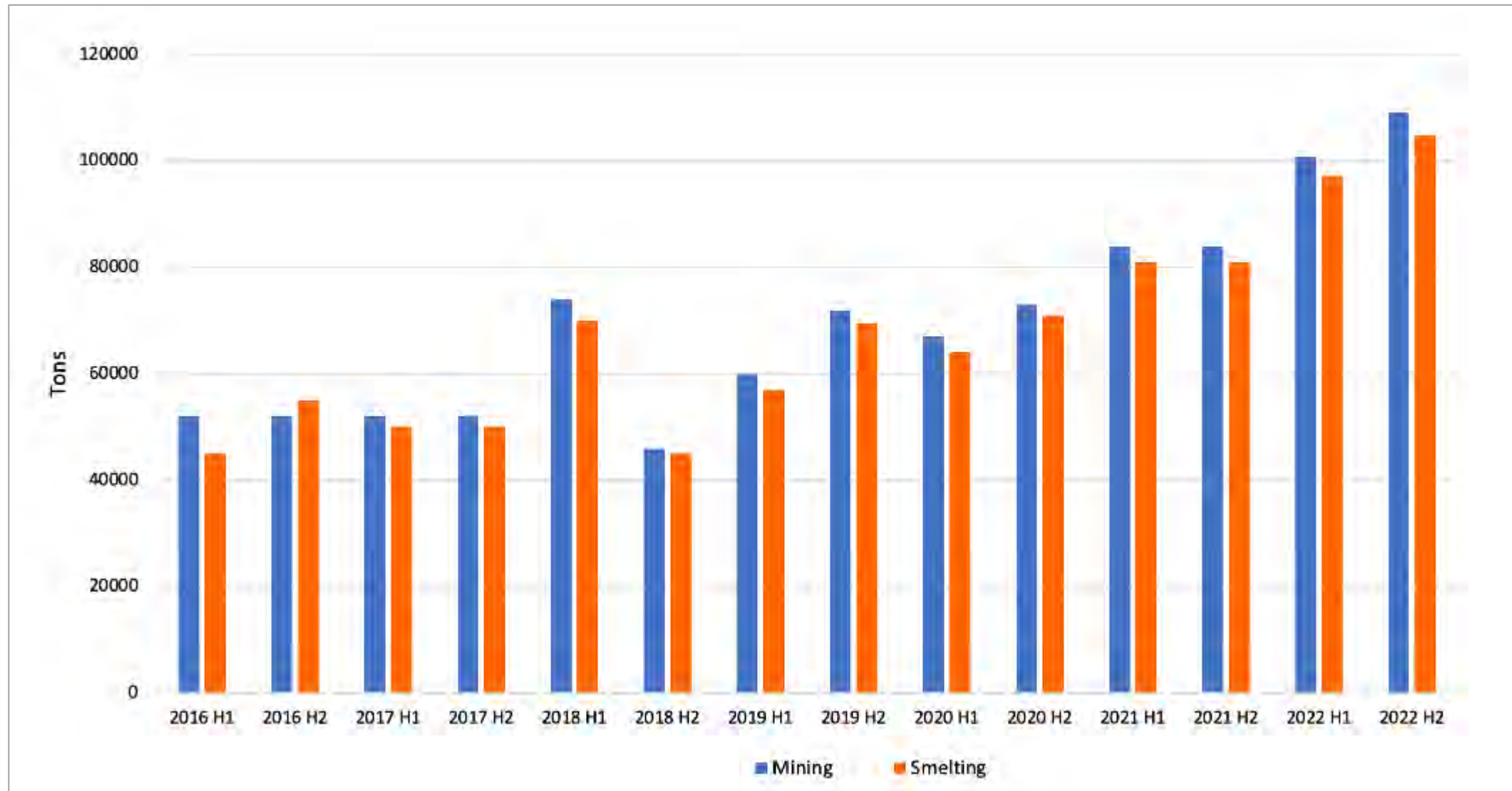


# Closer Look: REE



Elonso, et al., 2015 data, <https://onlinelibrary.wiley.com/doi/full/10.1111/jiec.13354>

# China REE: The Power of Quotas





# China REE: Monoliths

Entity	Subscribed Capital	Shares Ratio
SASAC (State-owned Assets Supervision and Administration Commission of the State Council)	RMB 31.21 million	31.21%
CHINALCO	RMB 20.33 million	20.33%
China Minmetals Co.	RMB 20.33 million	20.33%
China Southern Rare Earth Group	RMB 20.33 million	20.33%
China Iron & Steel Research Institute Group	RMB 3.9 million	3.9%
Grinm Group Co.	RMB 3.9 million	3.9%

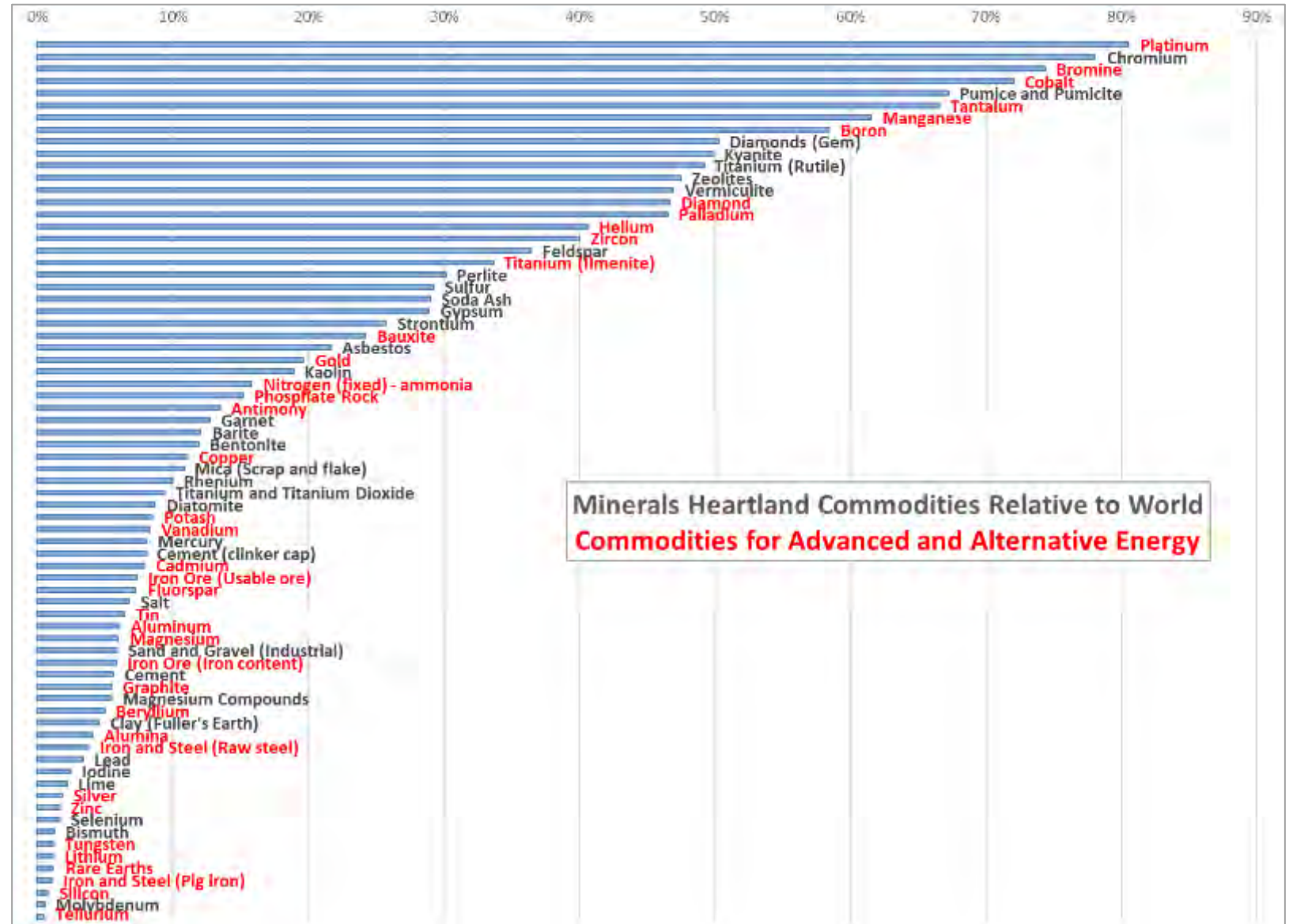
Policy	Global Supply	International Price	Chinese Price	Resilience
<i>Illegal mining and export</i>	Increase	Decrease (Negative effect)	Decrease (Negative effect)	Improve/strengthen
<i>Chinese environmental regulations</i>	Weaken	Increase (Positive effect)	Increase (Positive effect)	Demote/weaken
<i>Consolidation of rare earth enterprises</i>	Weaken	Increase (Positive effect)	Increase (Positive effect)	Demote/weaken
<i>State-sponsored stockpiling</i>	Weaken	Increase (Positive effect)	Increase (Positive effect)	Demote/weaken



# New Turf

***From KSA to UAE, the Gulf region, through Central Asia and across Africa, big ambitions.***

<https://www.bakerinstitute.org/research/defining-minerals-heartland-future-africa-central-asia>



# Raw Materials Sourcing Cycle: Common Challenges

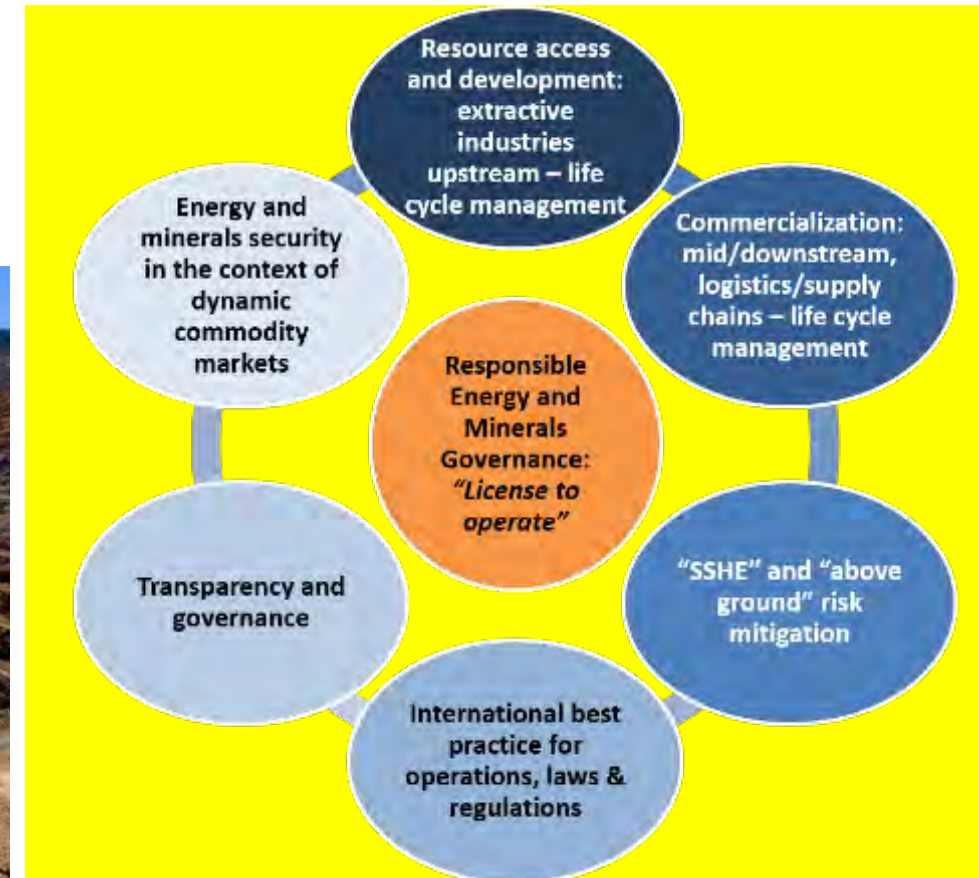
Build cognizance of supply chain and life cycle risks and uncertainties

- From raw materials **sourcing** to ultimate **end of life** management
- Attend to **economic, environmental, geopolitical security risks and uncertainties**
- Technology and policy approaches for **responsible development and use**
- **Can it be done profitably???**



Bingham Canyon Copper Mine, Utah

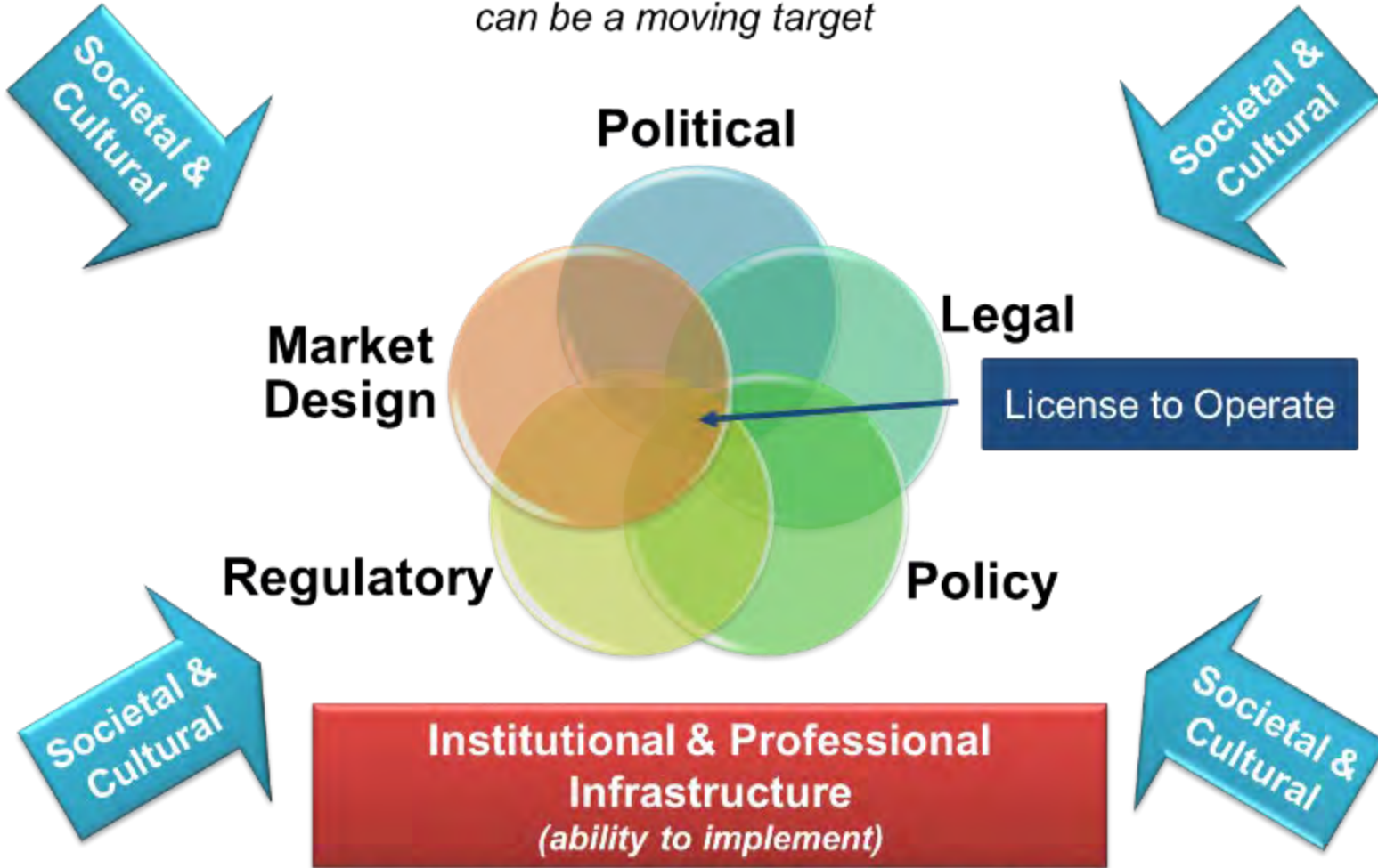
**“All value chains begin upstream”**



M. Michot Foss

# Commercial Frameworks

An 'Evolving Bargain' \* – Rules of the game for can be a moving target

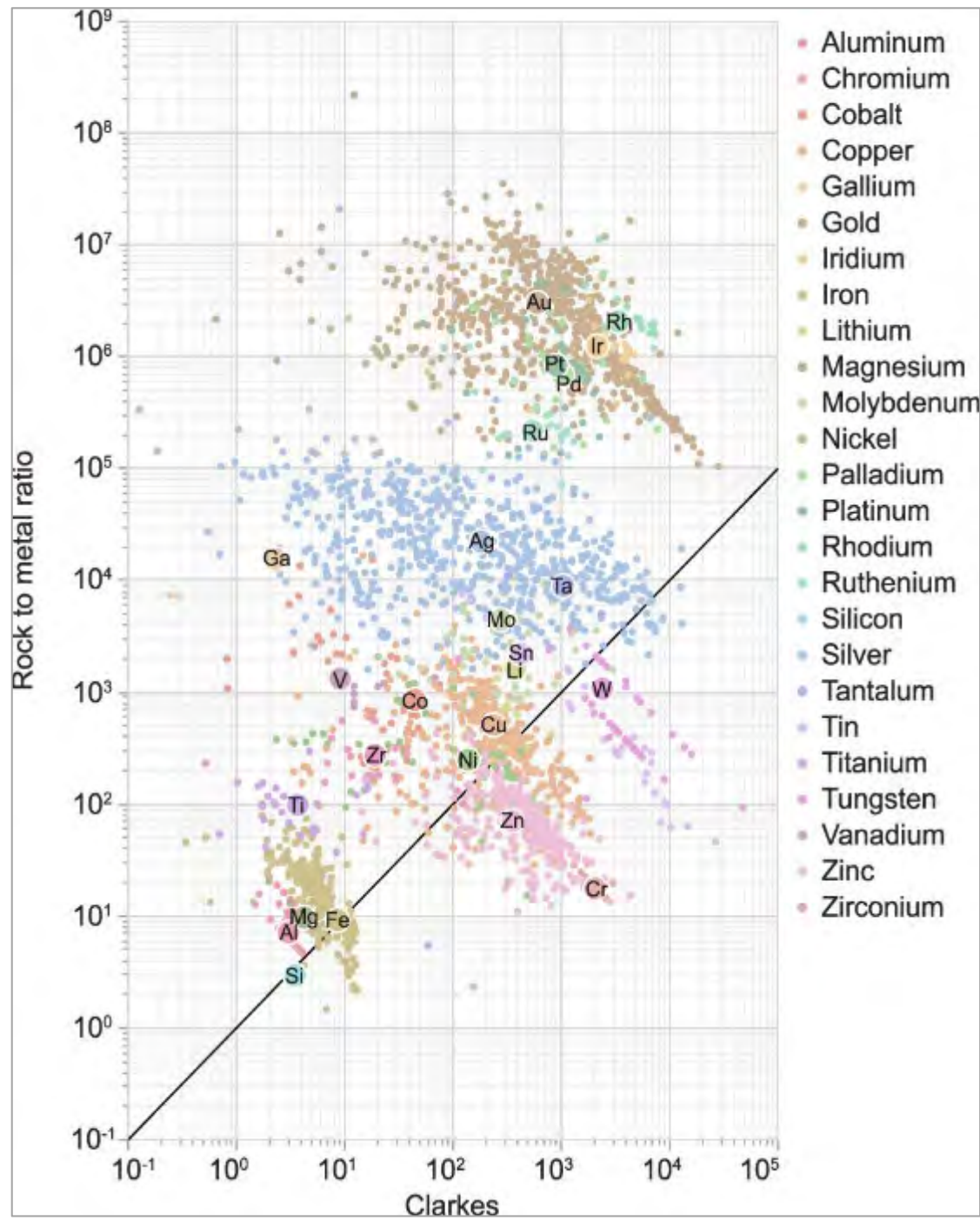
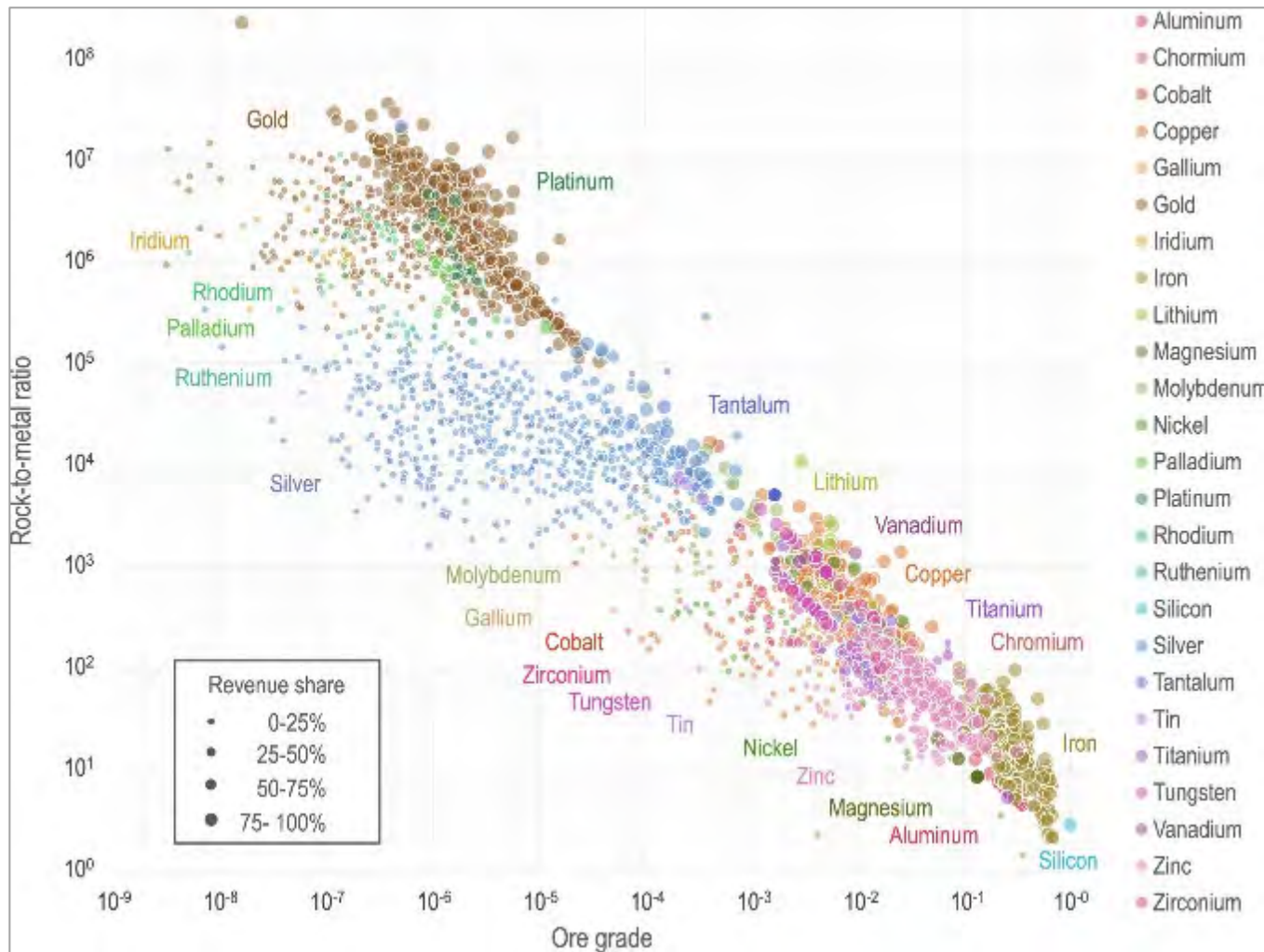


\* Phrasing from Emmons, *The Evolving Bargain*, 2000, HBS Press



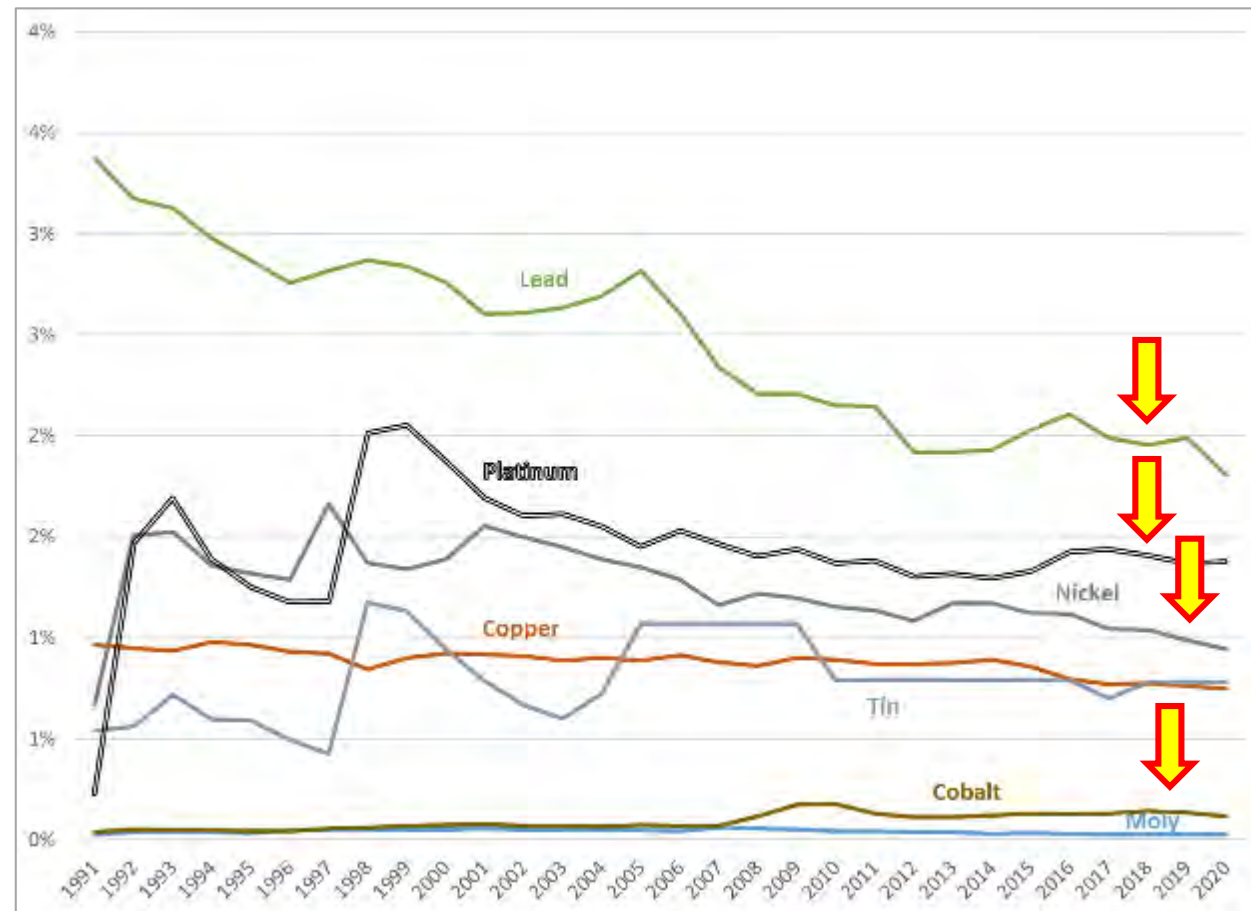
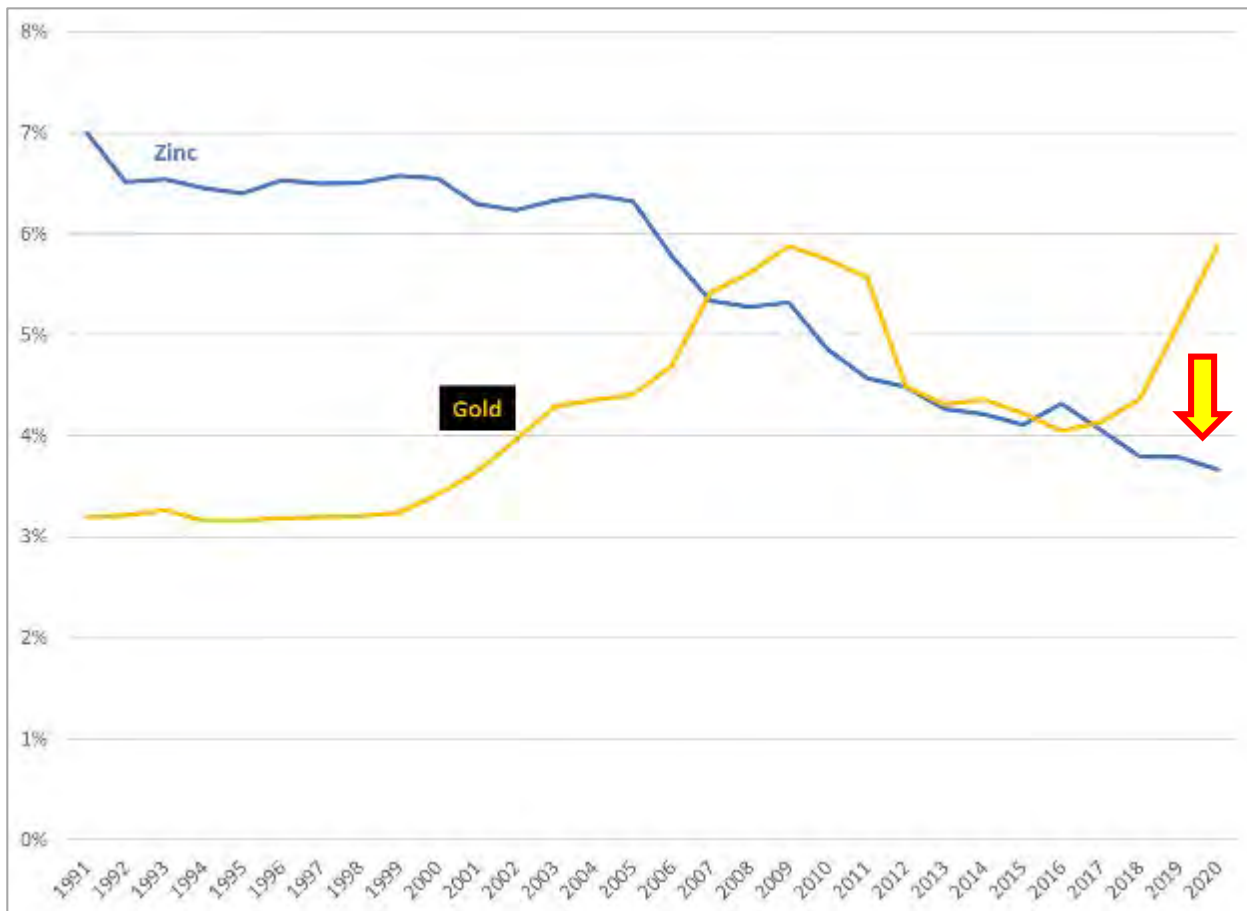
# Challenge of Minerals Occurrence

Rock-to-Metal Ratio, Nassar, et al, *Environmental Science & Technology* 2022 56 (10), 6710-6721, DOI: 10.1021/acs.est.1c07875



# Challenge of Commercialization

*Historical head grades from operational data.*



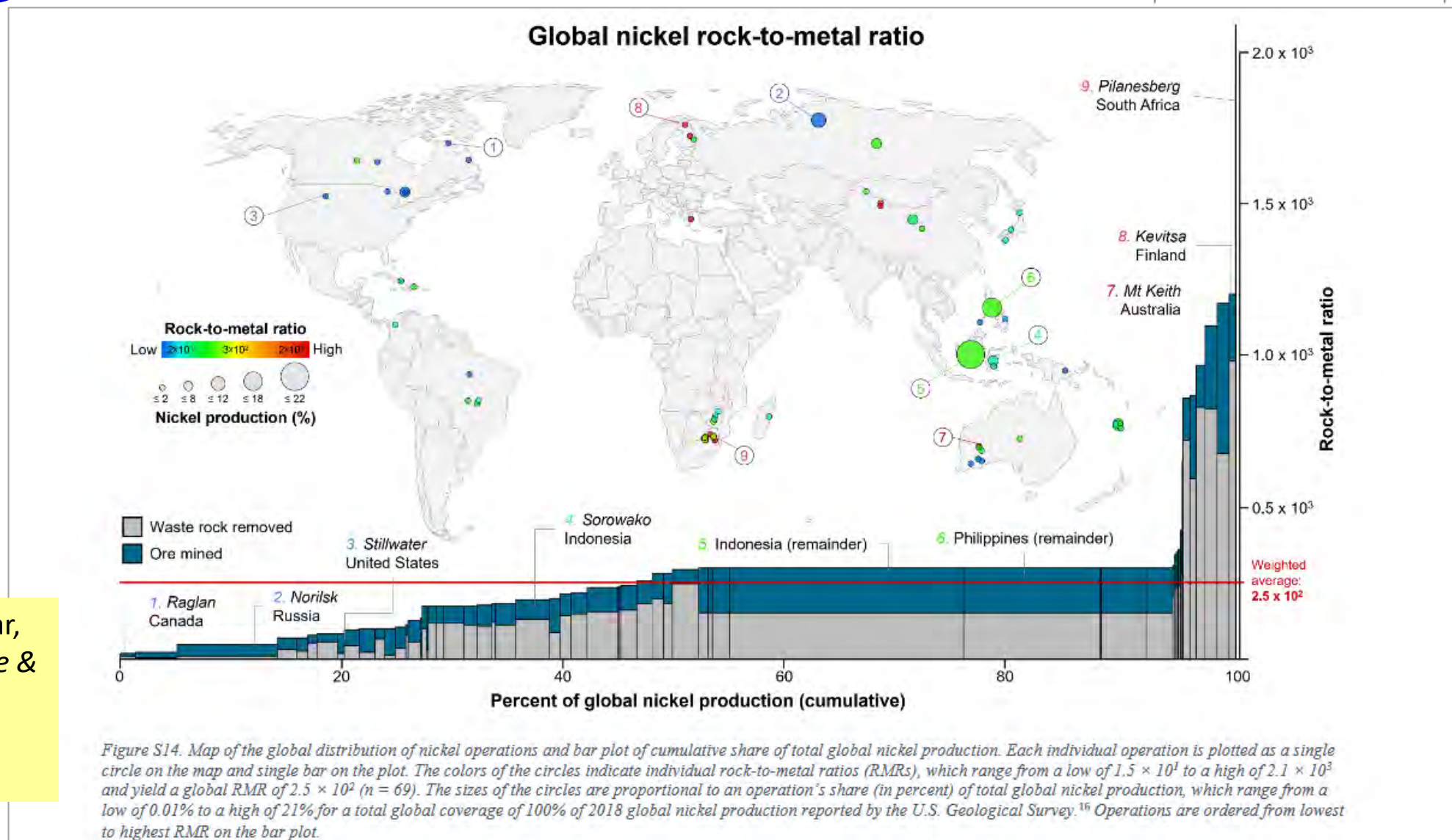


# Challenge of Waste

See nickel case study in [Lagniappe](#)

“The world is full of red muds.” Yet-  
Min Chiang, MIT  
@ DOE ARPA-E  
summit, May  
2022, Denver.

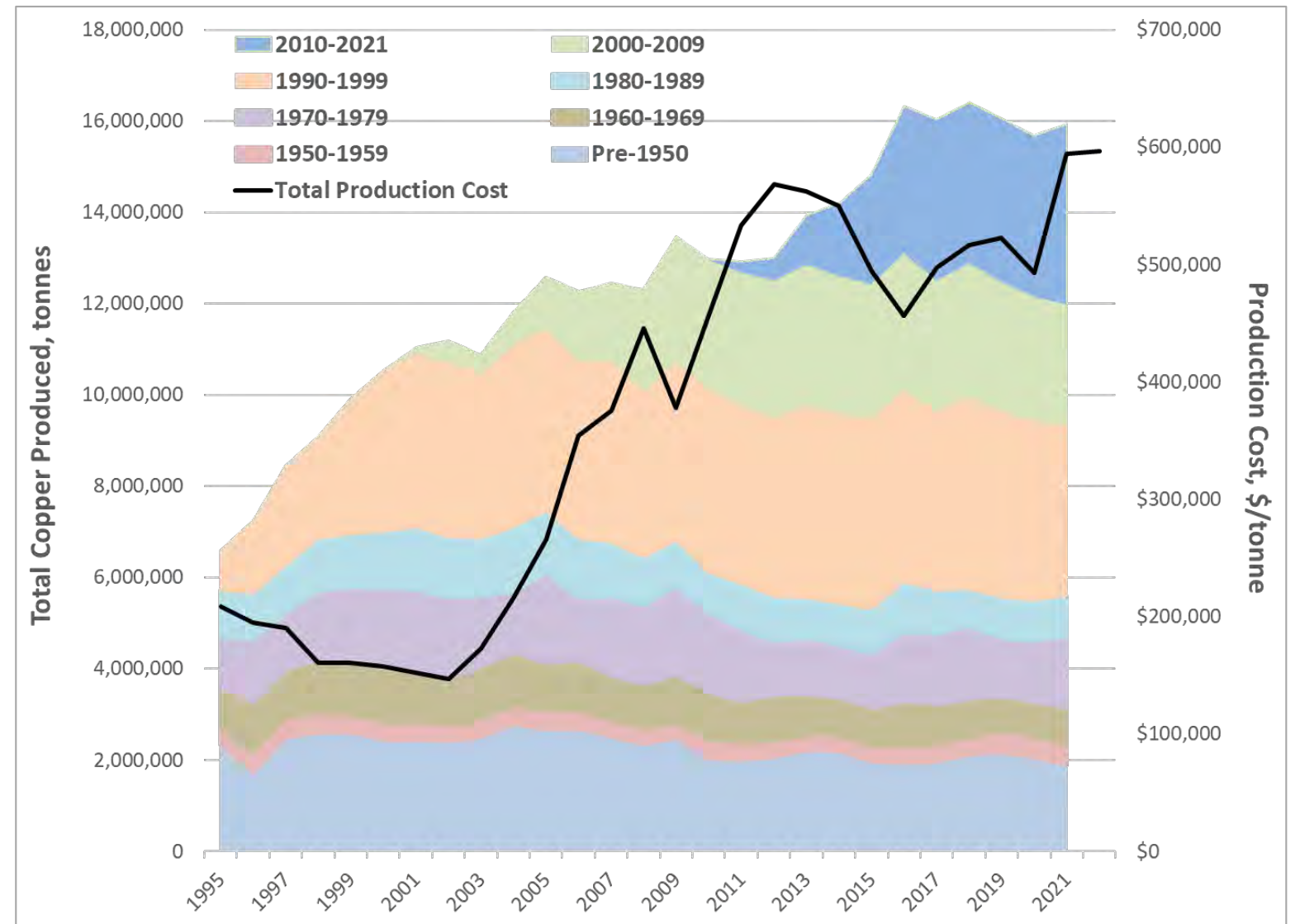
**Rock-to-Metal Ratio**, Nassar, et al, *Environmental Science & Technology* 2022 56 (10), 6710-6721, DOI: 10.1021/acs.est.1c07875





# Challenge of Sustaining Supply: Copper

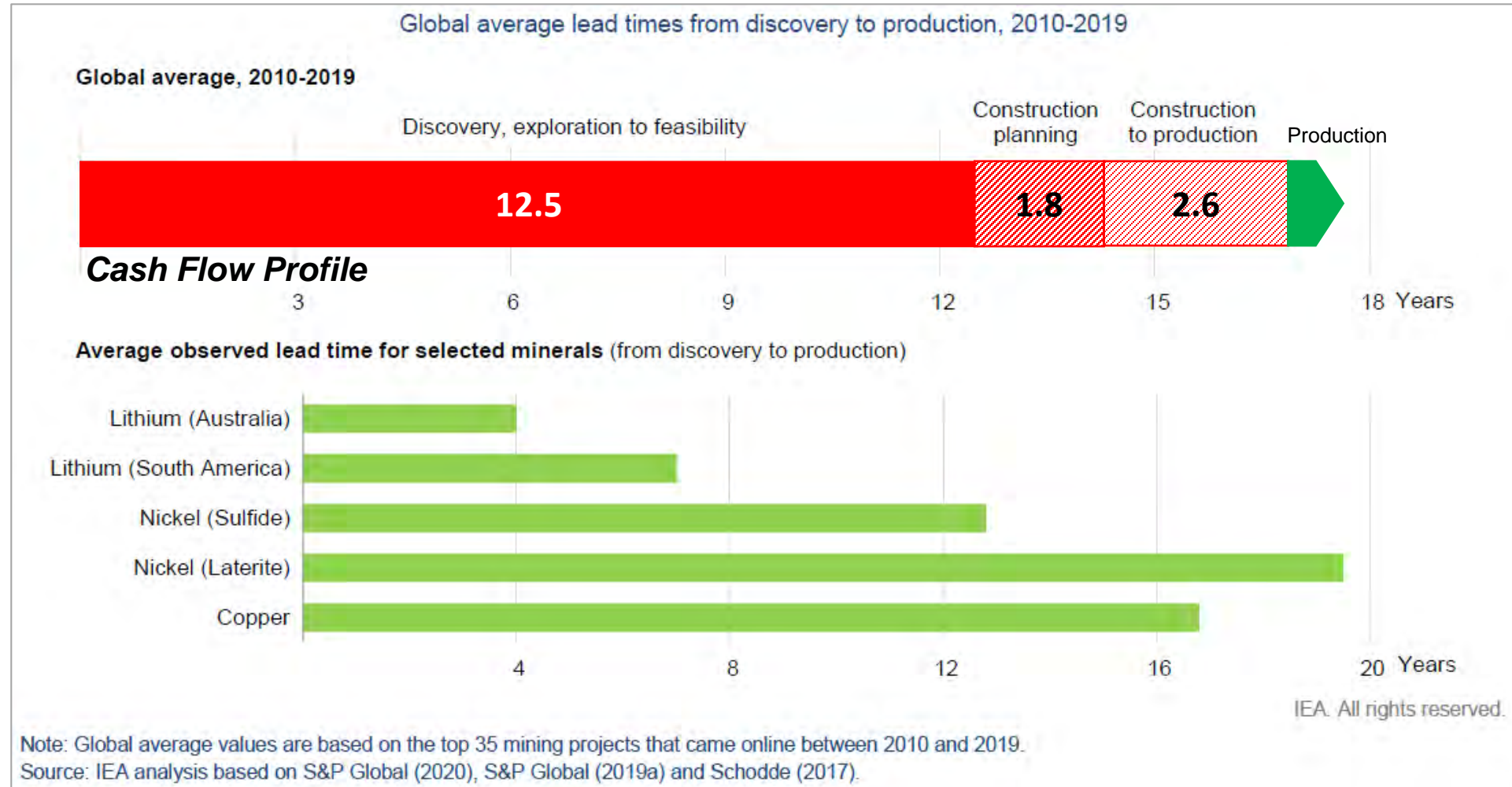
- Vintaged copper supply stack captures ~80% global production.
- **Nearly 40% of current output is from assets older than 1990.**
- Many of these are not “ESG compliant”.
- Many of the largest, older assets remain in operation because decommissioning not practical.
- As assets age, ore grades decline, paid metal to waste, rock to metal ratios deteriorate.



MM Foss using SPG, accessed via license. Work in progress.

# NIMTO = “not in my term of office” Challenge of Project Cycle Times

**“U.S. Mining:  
Heightened Risks Of  
Regulatory Changes  
As Resource  
Nationalism  
Intensifies Globally”**  
Fitch Solutions / Mining /  
United States / Tue 12 Oct, 2021  
<https://www.fitchsolutions.com/mining/us-mining-heightened-risks-regulatory-changes-resource-nationalism-intensifies-globally-12-10-2021>



IEA, <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>  
Note – cash flow profile modified from IEA original graphic by author.



# Why have U.S. smelters shutdown?



- Many smelters were built close to ore bodies. When ore was exhausted, smelter was not located near low-cost transportation
- Starting in 1960s, some countries (Japan, India, S. Korea and China) recognized the economic benefit of supporting metal smelters leading to new or modernized facilities
- Metal commodity exchange warehouses led to stable but low metal prices. Margins became small leading to disincentives to modernized U.S. smelters to compete in global market
- U.S. government actively avoided supporting domestic metal production and instead pushed for the closure of "dirty, old smelters"

\$/lb



Dec. 1984



# Challenge of ESG in Mining and Metallurgy

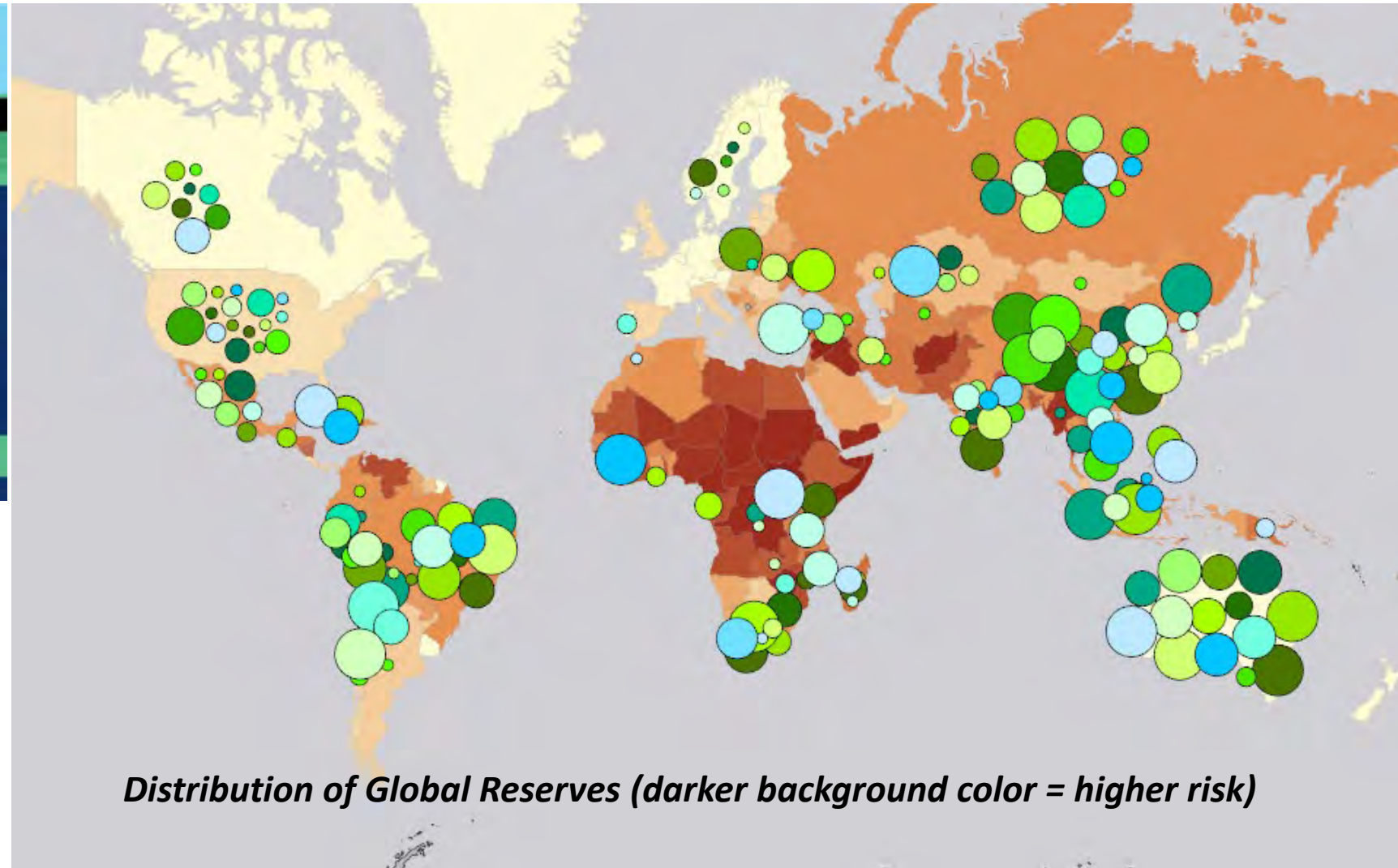
- Concept – the digital mine for optimization, efficiency, safety
- Upstream –
  - Fuel switching from diesel – electrification coincides with drive to automate (both reduced emissions and improved safety metrics BUT impacts labor force)
  - Remote tech and automation as much as possible – drones and robotics for explosives, robotics for extraction and removal
  - Waste and water reduction to extent possible, improved tailings management (safety and public protection), capture residual minerals from waste, options for water resources (community interface)
- Midstream/downstream –
  - Improved logistics – emissions reductions across supply chains
  - Automation and digitization
  - Pressure on contractors (many mine operations are contracted) and vendors
- For companies of all types – measuring, reporting
- Un-level playing fields – across counties, investors
- It will take a long time.....



# Challenge of Old Insecurities: The Problem of Fragile States



<https://www.iisd.org/library/green-conflict-minerals-fuels-conflict-transition-low-carbon-economy>





# Challenge of "Sustainability"

Kern County, CA



Copper-colored lubricant is seen on an Arizona SA wind turbine. Photographer: Karl Marlow/Bloomberg



Slud with contaminated rocks sit in front of a turbine tower. Photographer: Karl Marlow/Bloomberg



Puerto Rico, post-Maria



Germany's Push for Wind Power Encounters Resistance

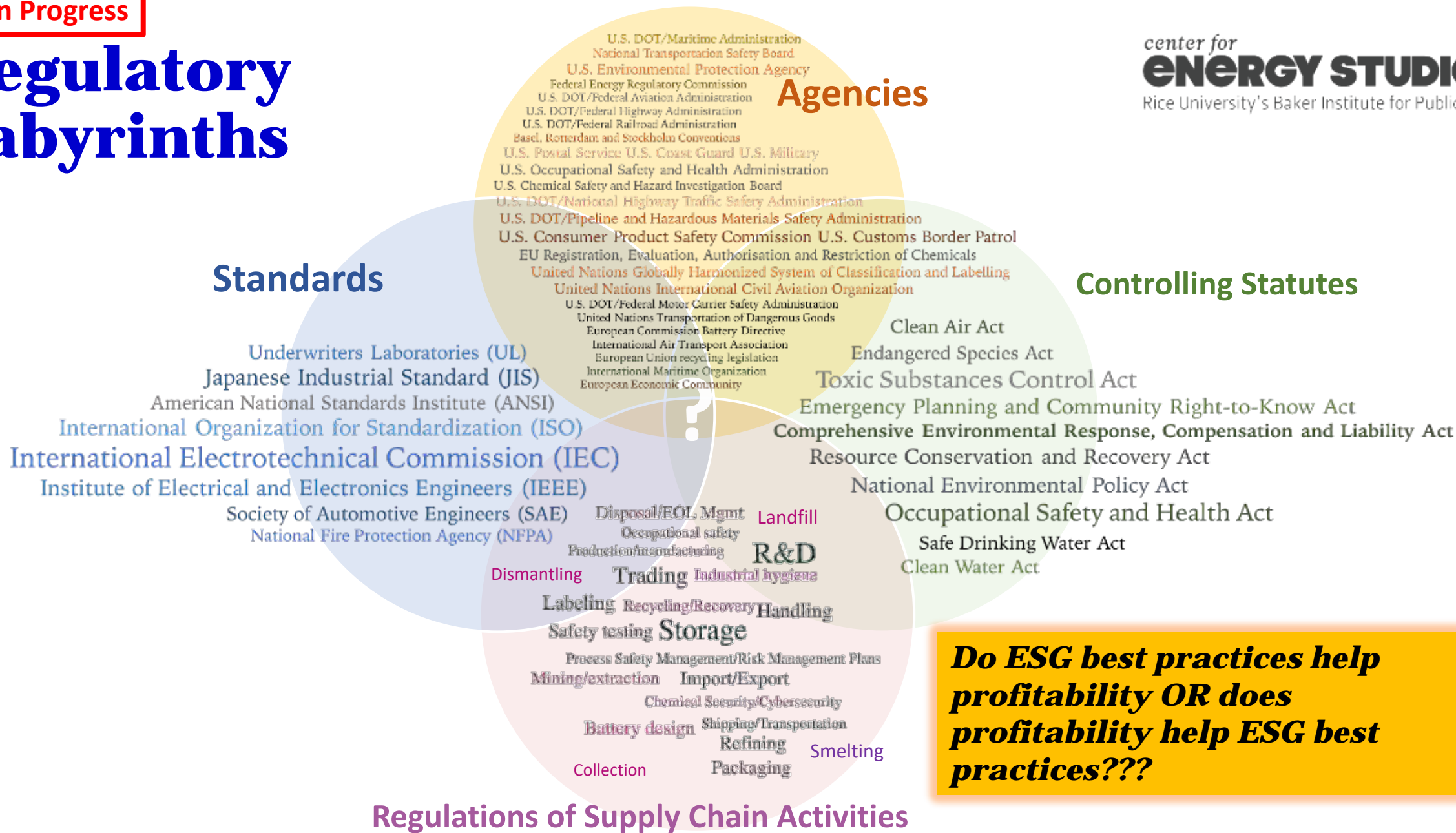
Community protests compound problems for an industry the government wants to promote



Fragments of wind turbine blades await burial at the Casper Regional Landfill in Wyoming. Photographer: Benjamin Rasmussen for Bloomberg Green



# Regulatory Labyrinths

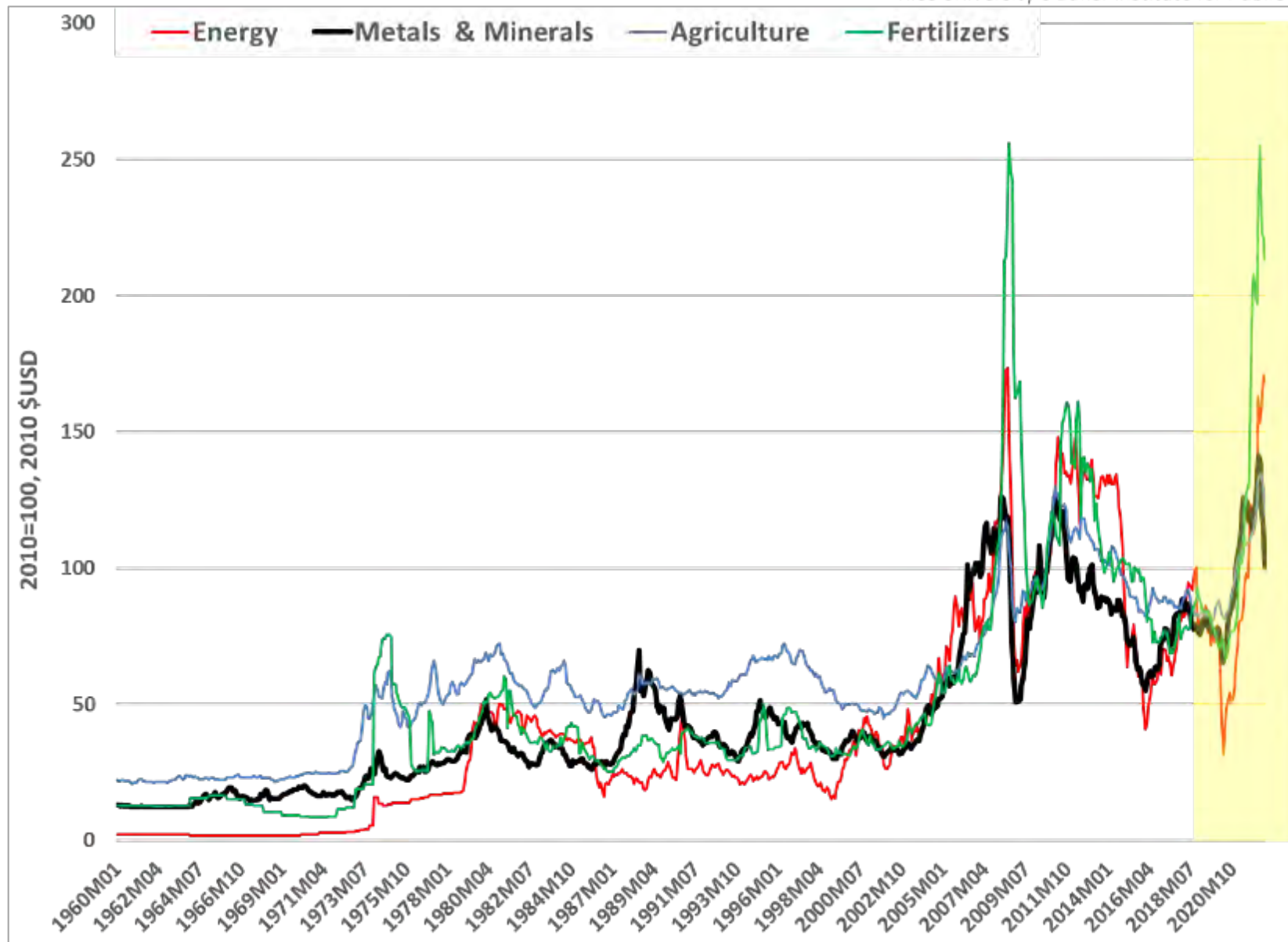


***Do ESG best practices help profitability OR does profitability help ESG best practices???***



# Challenge of “Greenflation”

*A Less “Transitory”  
More Expensive  
World?*



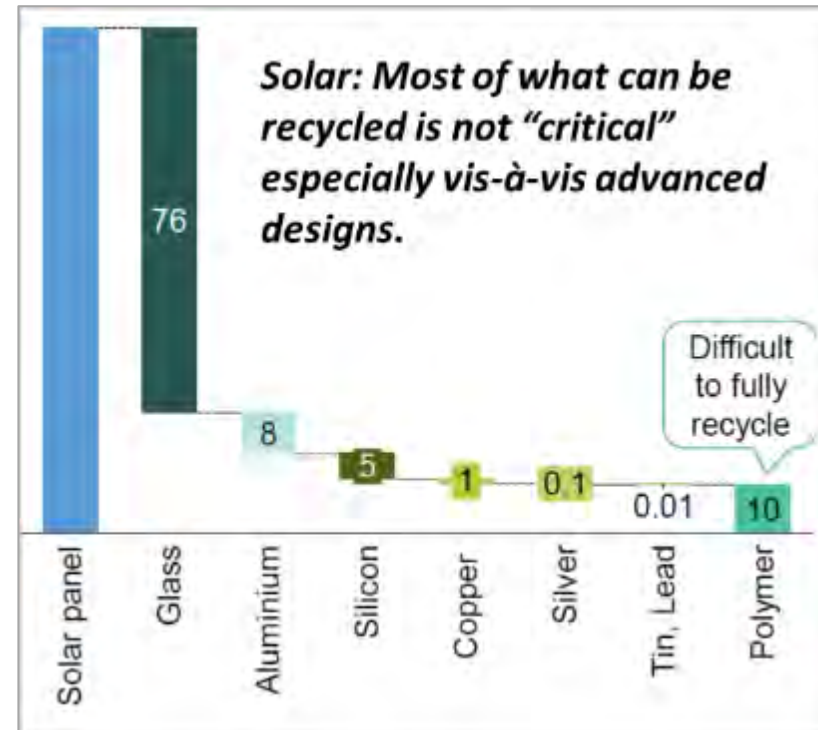
*M. Michot Foss based on  
World Bank Pink Sheet*

# Can we recycle our way out of it?

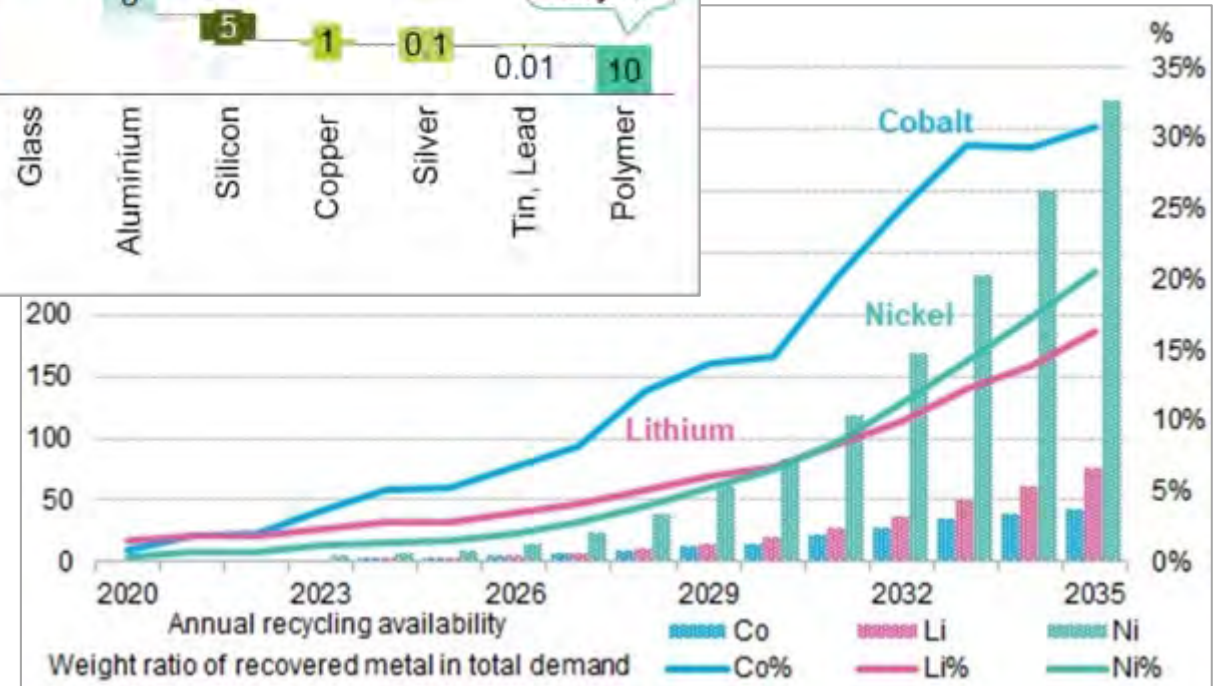
*It's not like we don't recycle....*

Commodity	U.S. Scrap Market Share
Iron & Steel	58%
Aluminum	53%
Copper	34%
Lead	71%
Zinc	25%
Nickel	52%

- **Recyclers must achieve comparable quality for sensitive applications (black mass to hydrometallurgy to purity required)**
- **Metals are ~9% of U.S. municipal solid waste. Plastics ~12%.**
- **Global plastics recycling ~9-20% depending upon polymer. "Bio-plastics" ~1%**
- **Forthcoming CES/BIPP brief on plastics and metals recycling.**



*Batteries: The higher the commodity price, the better the potential profitability.*



# Can we substitute our way out of it?

***The allure of advanced carbon materials.....sourced from conventional oil and gas; methane pyrolysis; CO2 capture including direct air capture. Carbon nanotube (CNT) materials in particular provide substantial improvements in thermal, electrical conductivity.***

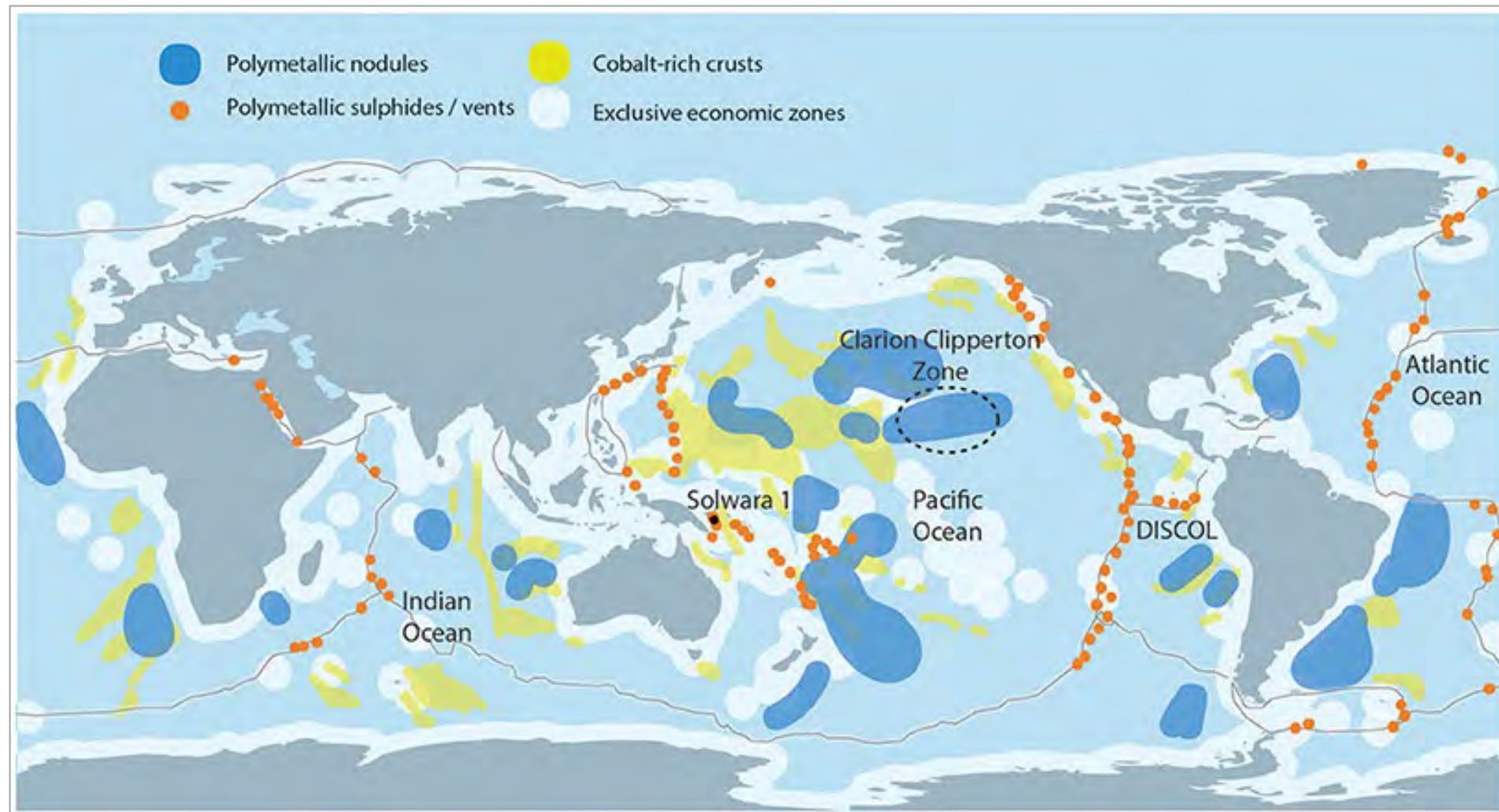
Scarce metal	Main application	Number of patents	Number of papers	Substitution level	Carbon nanomaterial substitute
Indium (In)	Transparent electrodes	18	>100	Material	G, CNT
Gallium (Ga)	Semiconductors	8	>100	Material	G, CNT
Beryllium (Be) and silver (Ag)	Conductive materials	6	>100	Material (Be) and elemental (Ag)	G, CNT
Antimony (Sb)	Flame retardants	5	>100	Material	G, CNT, F
Cobalt (Co), niobium (Nb) and tungsten (W)	Strong materials	5	>100	Material	G, CNT, F
Chromium (Cr)	Corrosion protection	3	>100	Material	G, CNT, F
Tantalum (Ta)	Capacitors	3	>100	Material	G, CNT
Tin (Sn)	Solders	2	22	Material	CNT
Germanium (Ge)	Optical fibers	0	2	Material	G, CNT
Platinum (Pt)	Catalytic converters	0	2	Element	G
Gold (Au)	Jewellery	0	0	—	—

<https://www.sciencedirect.com/science/article/pii/S0959652617307564>



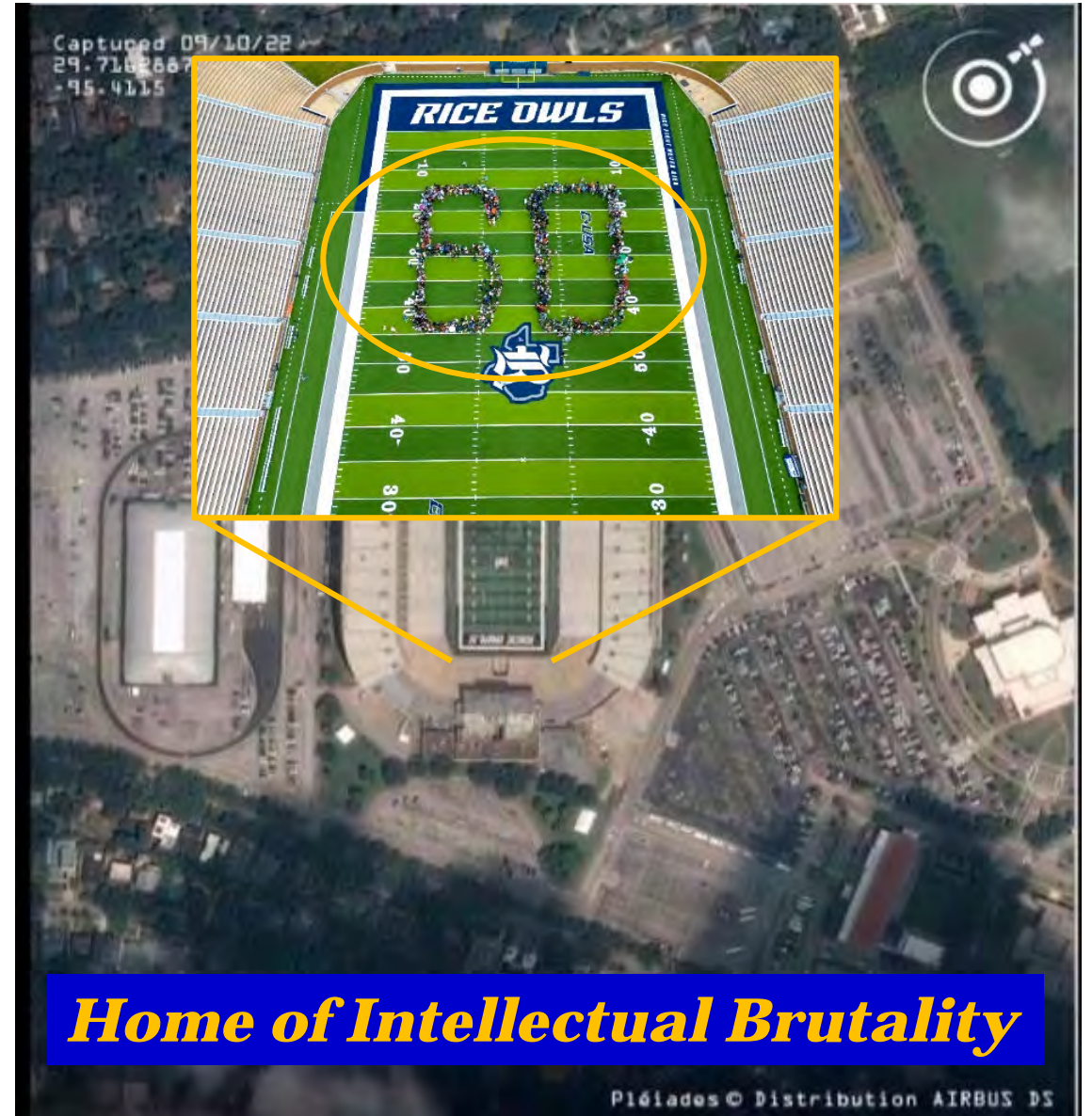
# Can we explore our way out of it? Frontiers: The Allure of the Oceans

- **Forthcoming brief**
- **Offshore Technology Conference 2023, Critical Minerals Panel, May 2**



Miller et al., *Front. Mar. Sci.*, 10 January 2018 | <https://doi.org/10.3389/fmars.2017.00418>

*Can we explore our way out of it?*  
**Frontiers: NOPE!**



NASA; Airbus/drone - <https://www.rice.edu/jfk60>

# Conclusion: Putting Materials First

- A strong rationale for slowing down, AND/OR doing something else
  - Questionable outcomes from green rushes – hidden costs, domino effects
- No alt energy incentives without materials forethought
  - Including semiconductors and other industrial policy targets
- Industrial policy means subsidies
  - Subsidizing incumbents creates barriers to invention and innovation
- Metals displacement, enhancement
  - Long history of “lightweighting” with plastics – train out of station
  - Carbon nanotube materials are alluring for performance – CNT alone or with metals doping for heavier duty products, desirable properties
    - But CNT challenges must be addressed head on
  - A potential way out of Chinese entanglements – but requires a complete “reset”



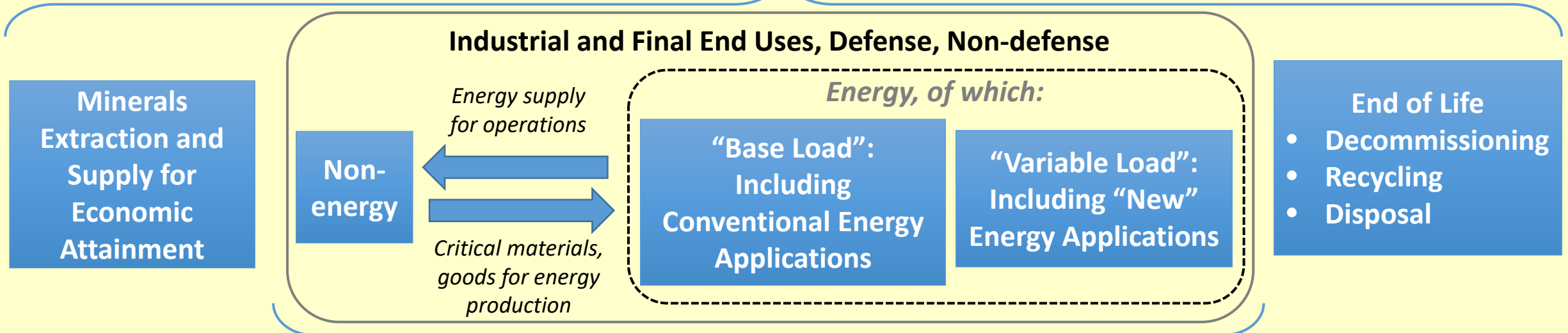
*A Little Something Extra*

**Lagniappe**

# G20 Proposed Recommendation (Rice/Missouri S&T) Critical Minerals/Materials Framework for Consideration

**Contingencies: technology and applications, materials and materials inputs, global energy/minerals supply/deliverability security**

**Supply “push” effects include SSHE risks/uncertainties and life cycle management: policy/regulatory architecture and development, standards, international coordination**



**Demand “pull” effects include: commodity markets, fiscal/monetary, affordability**

**SSHE = Safety, security, health, environment**

# World Mining Data Minerals Classification and Examples

<https://www.world-mining-data.info/>

## **Iron and Ferro-Alloy Metals:**

**Iron**, Chromium, **Cobalt**, **Manganese**, Molybdenum, **Nickel**, Niobium, Tantalum, Titanium, Tungsten, Vanadium

## **Non-Ferrous Metals:**

*Aluminium*, Antimony, Arsenic, Bauxite, Beryllium, Bismuth, Cadmium, **Copper**, Gallium, Germanium, Indium, Lead, **Lithium**, Mercury, Rare Earth Minerals, Rhenium, Selenium, Tellurium, Tin, Zinc

## **Precious Metals:**

Gold, Platinum-Group Metals (Palladium, Platinum, Rhodium), Silver

## **Industrial Minerals:**

Asbestos, Baryte, Bentonite, Boron Minerals, Diamond (Gem/Industrial), Diatomite, Feldspar, Fluorspar, **Graphite**, Gypsum and Anhydrite, Kaolin (China-Clay), Magnesite, Perlite, **Phosphate Rock** (incl. Guano), Potash, Salt, Sulfur, Talc (incl. Steatite and Pyrophyllite), Vermiculite, Zircon

**NOTE basics: Current commercial Lithium-ion battery types: LFP or LiFePo (**Iron, Phosphate**) and NMC or LiNiMnCo (**Nickel, Manganese, Cobalt**) with *Aluminium* **Graphite** electrode and **Copper** conductivity.**

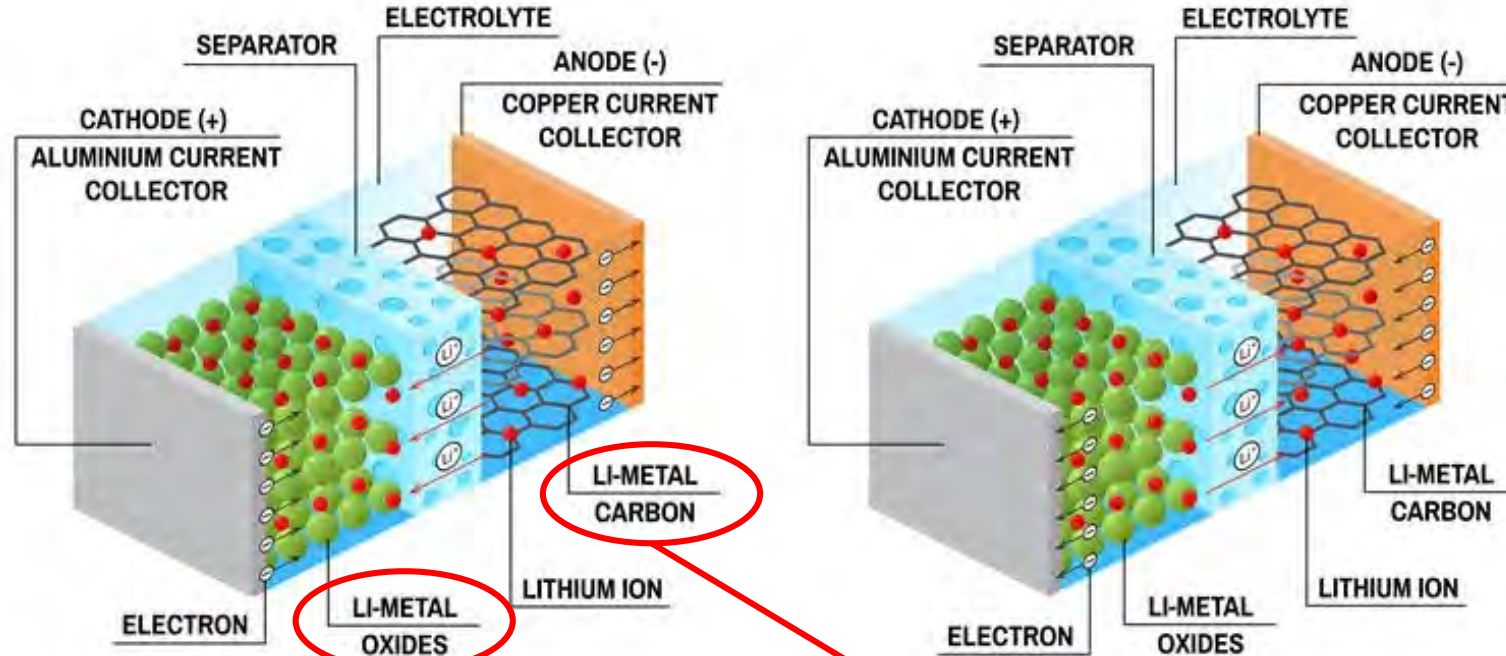


# General Battery Concepts

## LITHIUM-ION BATTERY

DISCHARGE

CHARGE



*LFP – Iron,  
Phosphorous  
NMC – Nickel,  
Manganese,  
Cobalt*

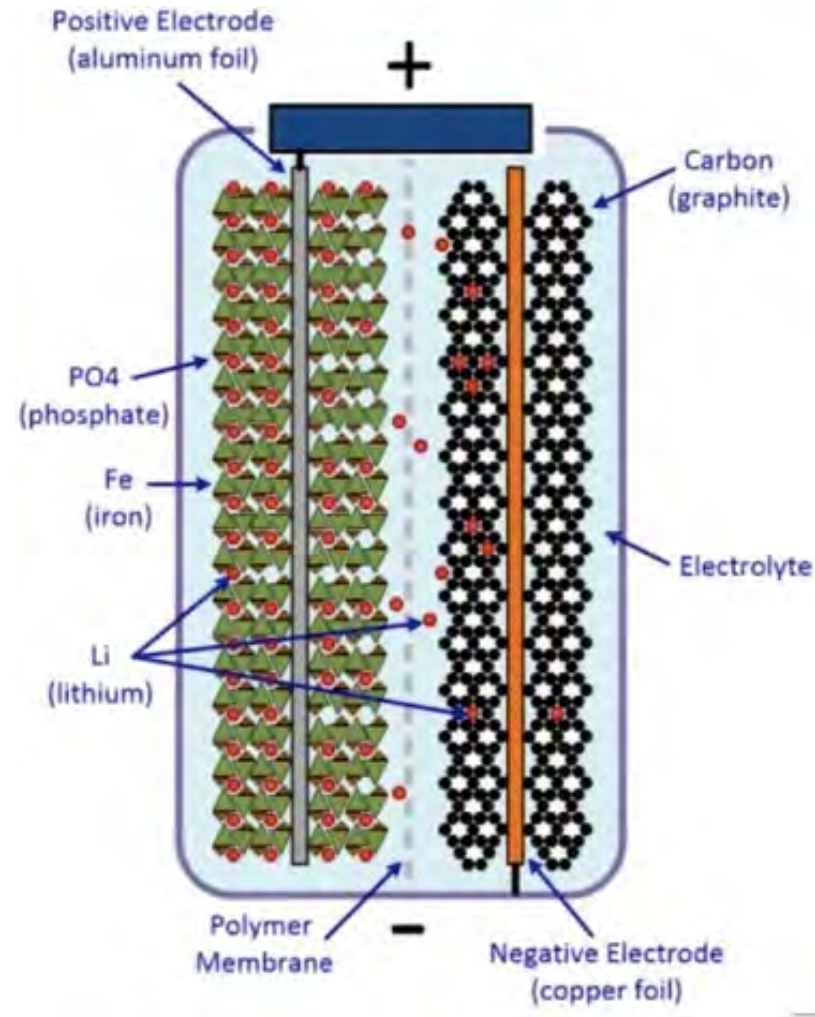
*Graphite*

# Main Commercial Chemistries



<https://nickelinstitute.org/blog/2020/june/battle-of-the-batteries-cost-versus-performance/>

# The Tesla LFP



<https://www.allaboutcircuits.com/news/a-closer-look-at-lithium-iron-phosphate-batteries-teslas-new-choice-of-battery/>



# Highlights of CES Nickel Case Study

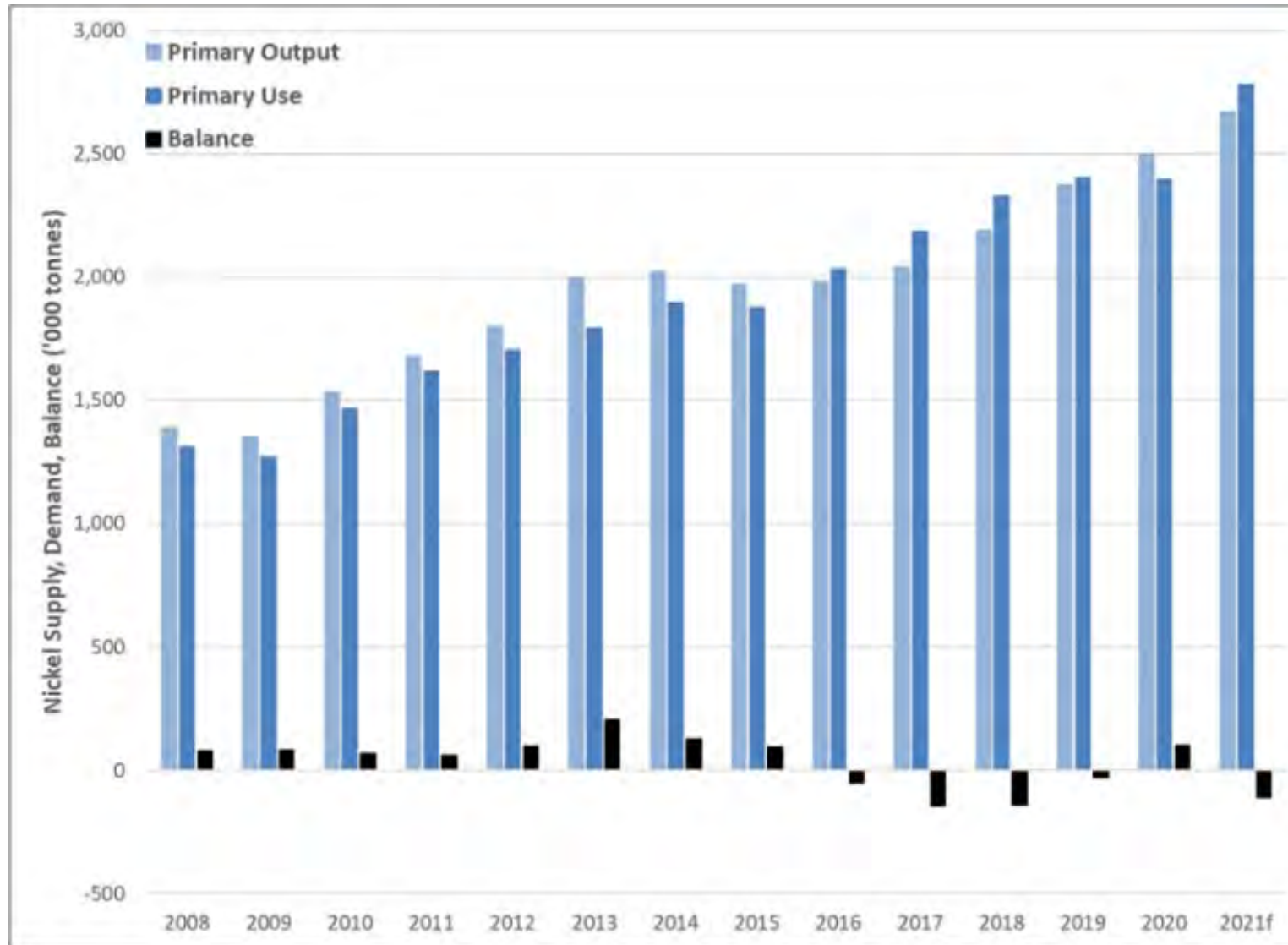
- A Chinese gamble to seize premium pricing for laterites
- SME Thrive, September 22, 2022
- See [Suggested Resources and Links](#)

# A Story About Quality

Mineral Production by Country - 2021



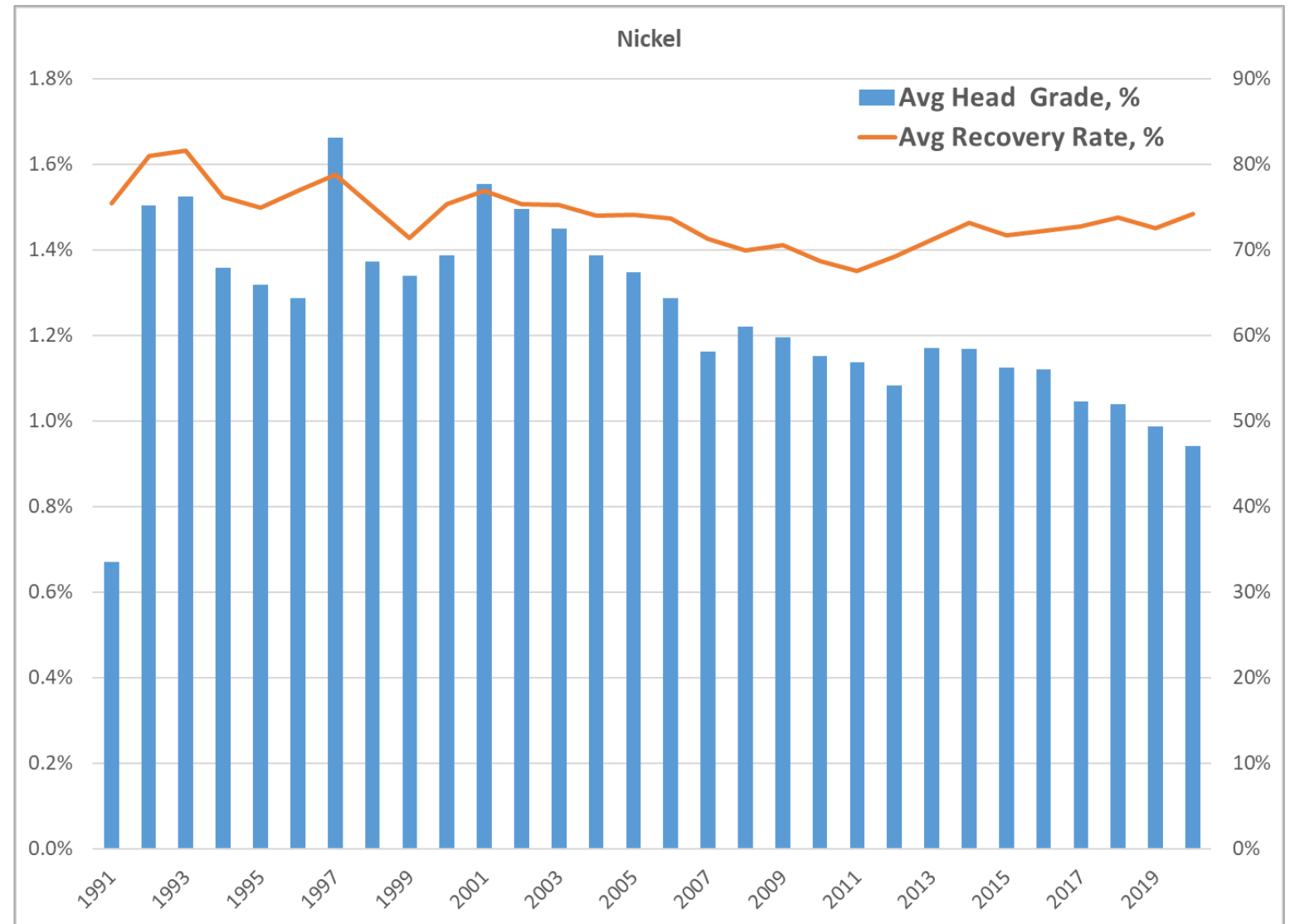
# Historical Supply-Demand Balances





# Global Recovery Rates and Production

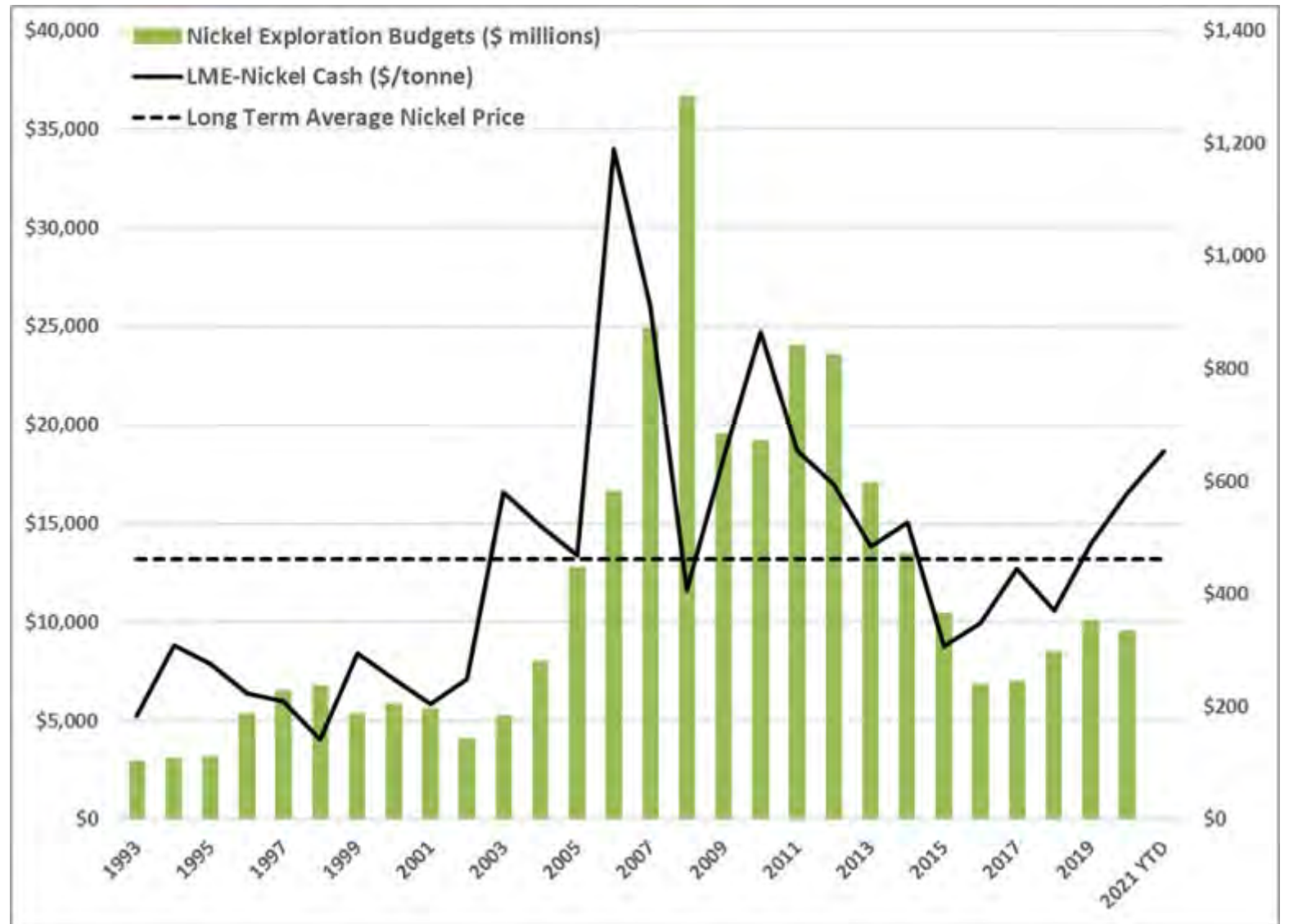
- Head grades reflect maturity across active properties, low rates of exploration, discovery.
- Improvements in head grade reflect periodic discoveries/new assets.
- Recovery rates can be improved through capex infusions in processing, recovery from tailings, etc.



Author analysis based on SPG, accessed via license.

# Follow the Money

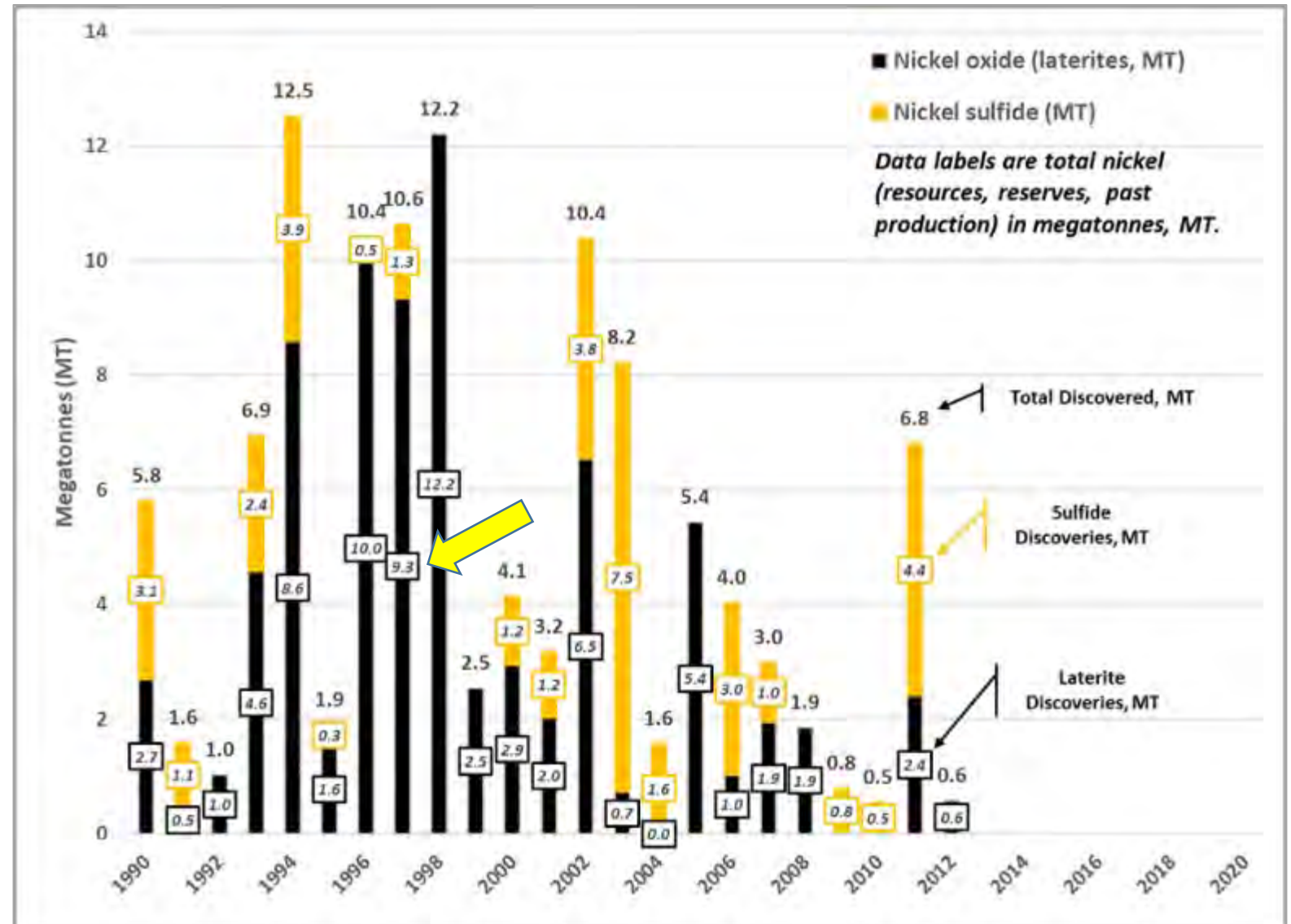
Exploration budgets follow risk-weighted expected returns, sensitive to price.



Author analysis based on SPG, accessed via license.

# Historical Nickel Discoveries

- No major discoveries since 2012.
- **Weda Bay**, with discovery confirmed in 1996 (reported in 1997, arrow) and an estimated 9.3 MT of producible reserves, serves as a good illustration of cycle time.
- From the point of discovery, which entailed prior years of drilling and testing, the property only entered operation in 2020, **some 25 years later**, with 0.0235 MT produced that year.

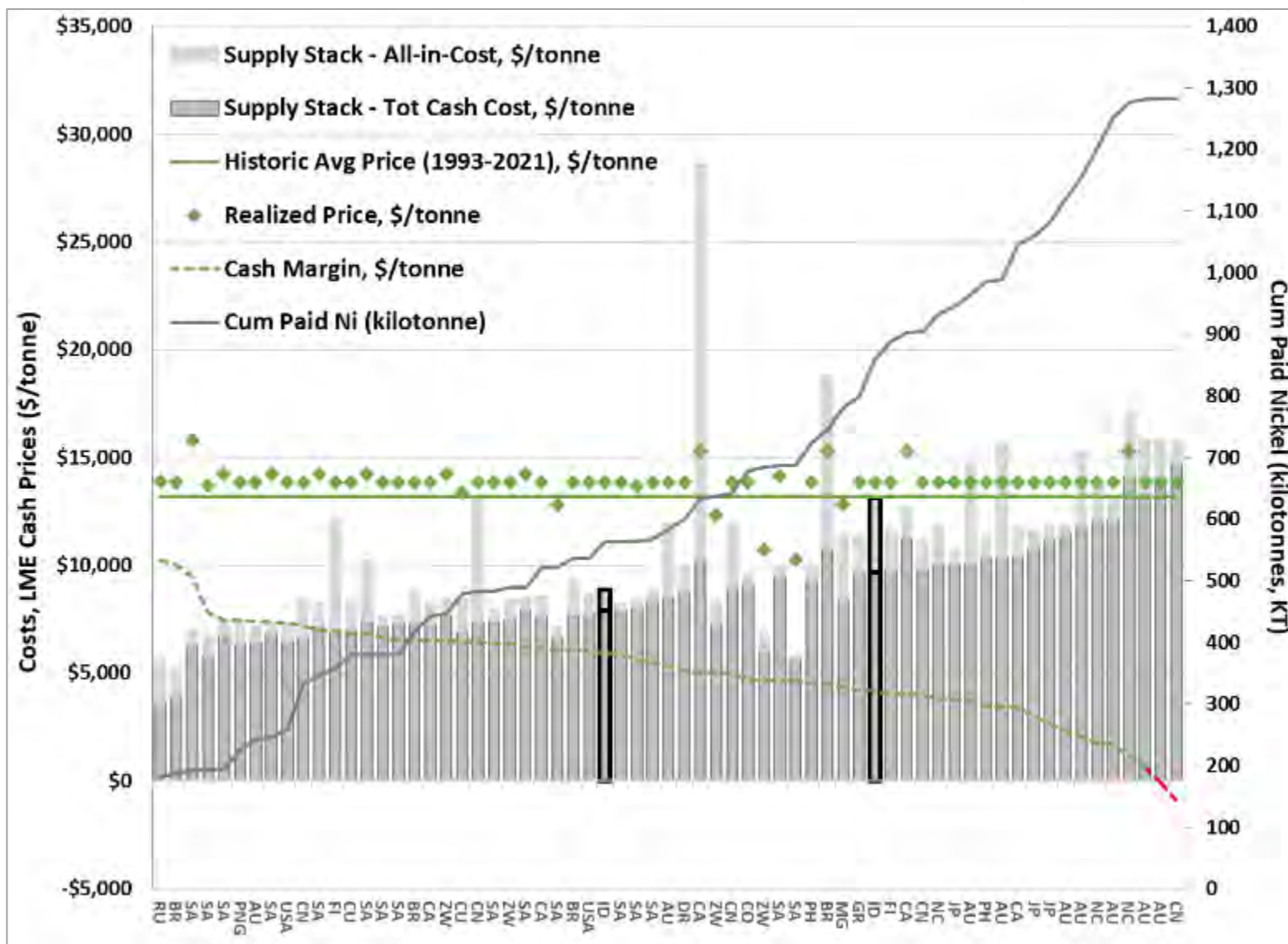


Author analysis based on SPG, accessed via license.



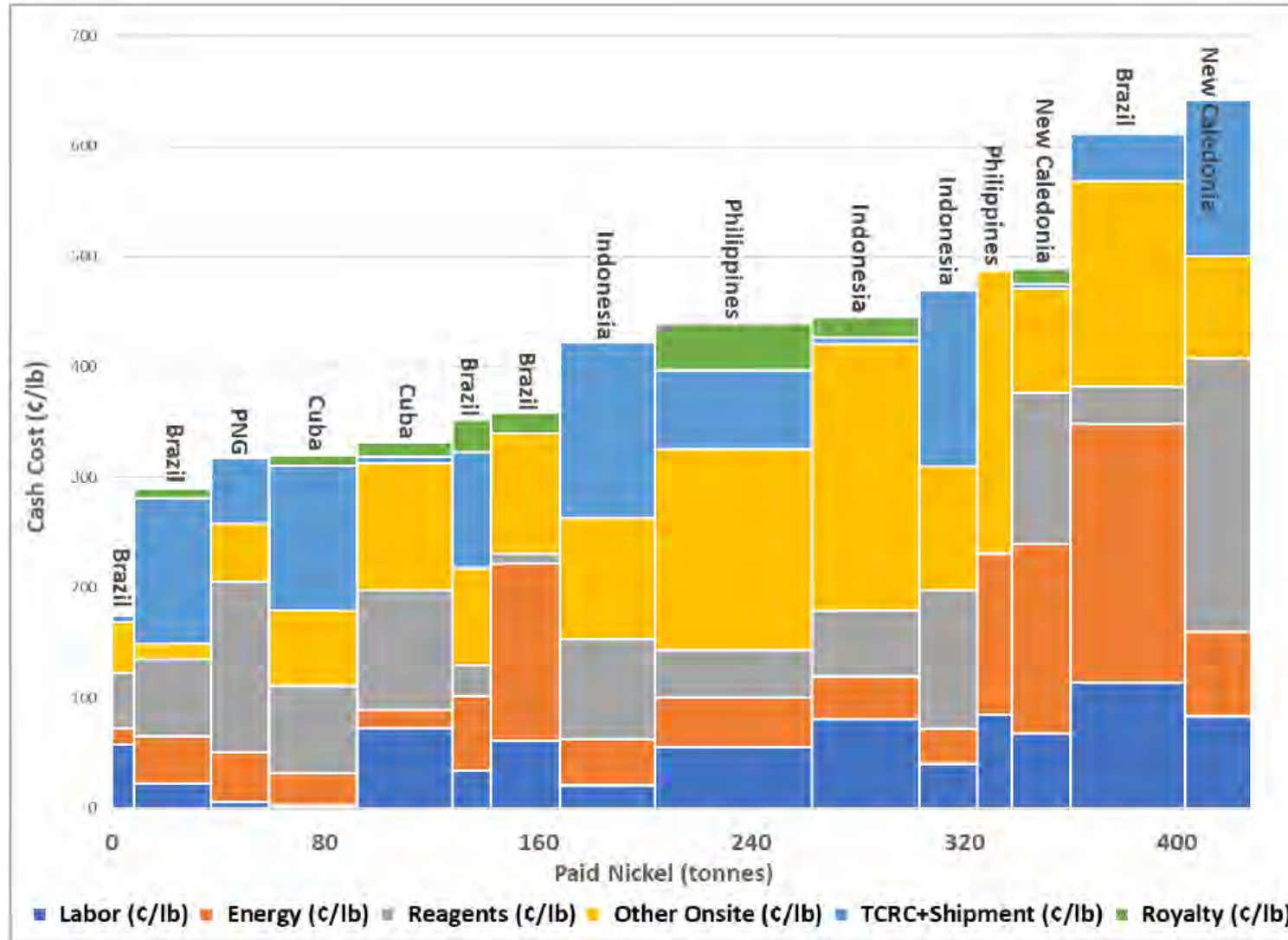
# Global Supply Curve

Cum paid metal, ranked by profitability.



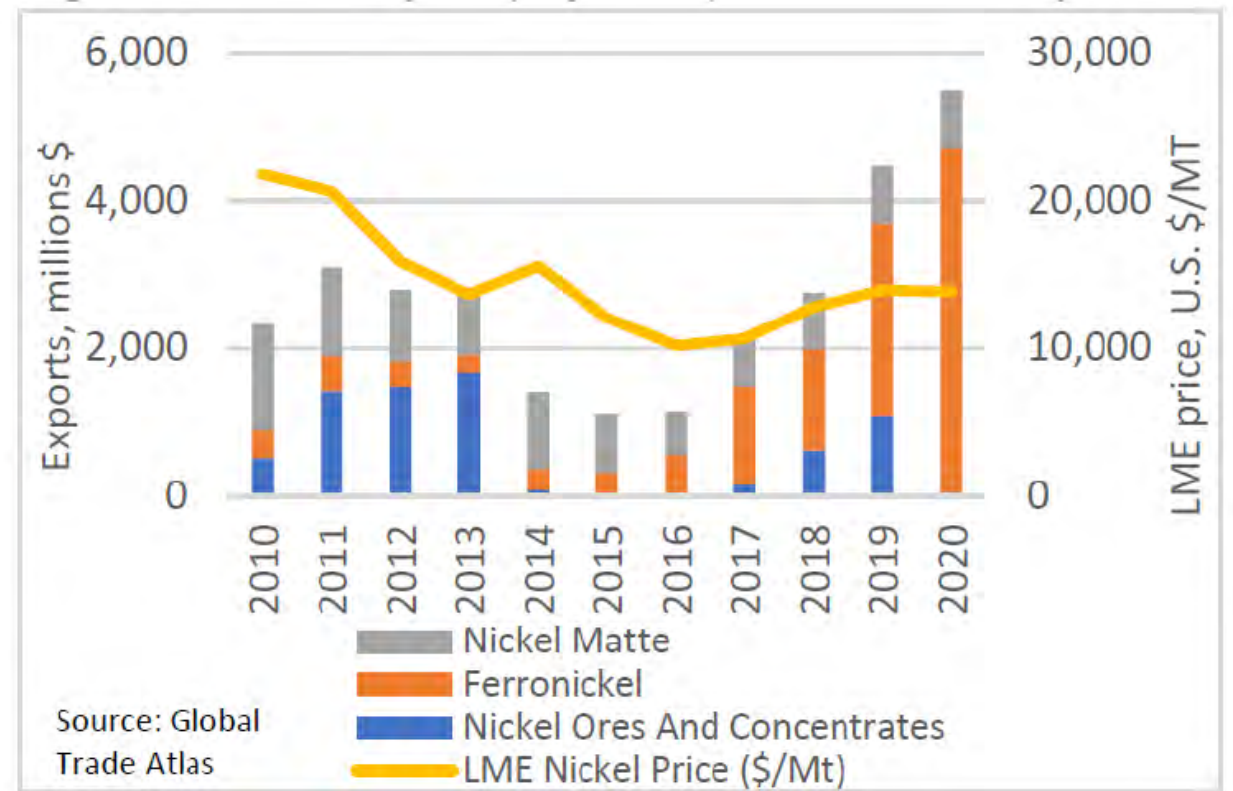
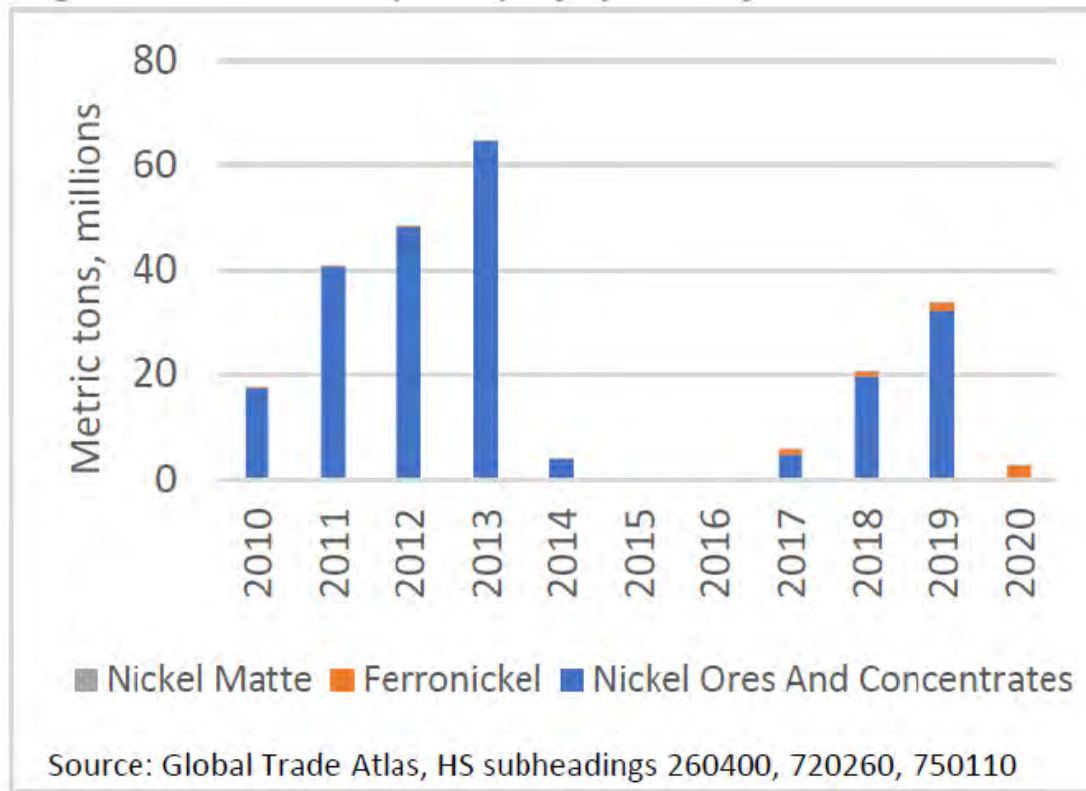
Author analysis based on SPG, accessed via license.

# Costs for Major Laterite Producers



Author analysis based on SPG, accessed via license.

# Indonesia Trade and Export Ban



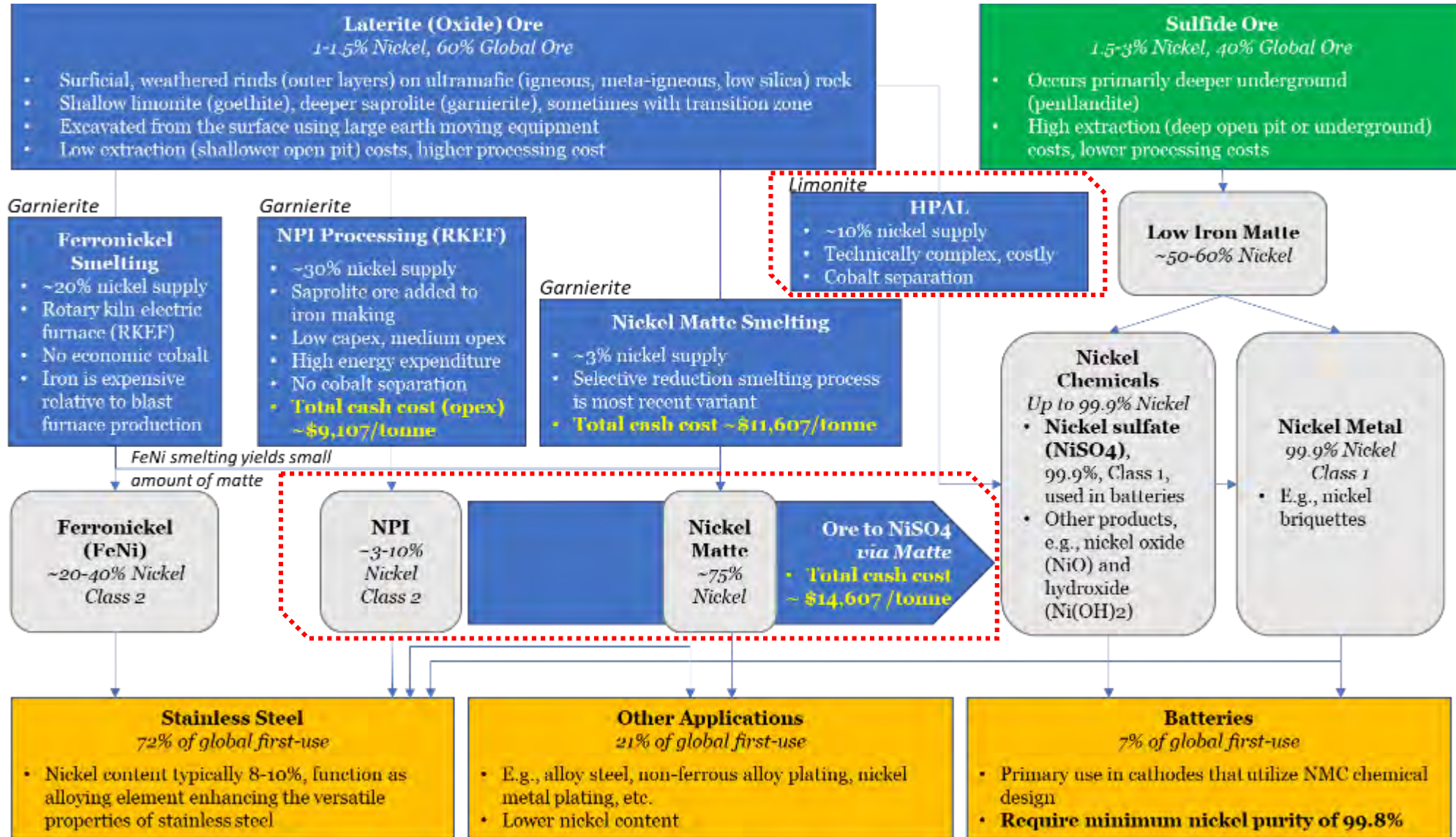
*USITC analysis, used with permission.*



# Generalized Nickel Processing Streams

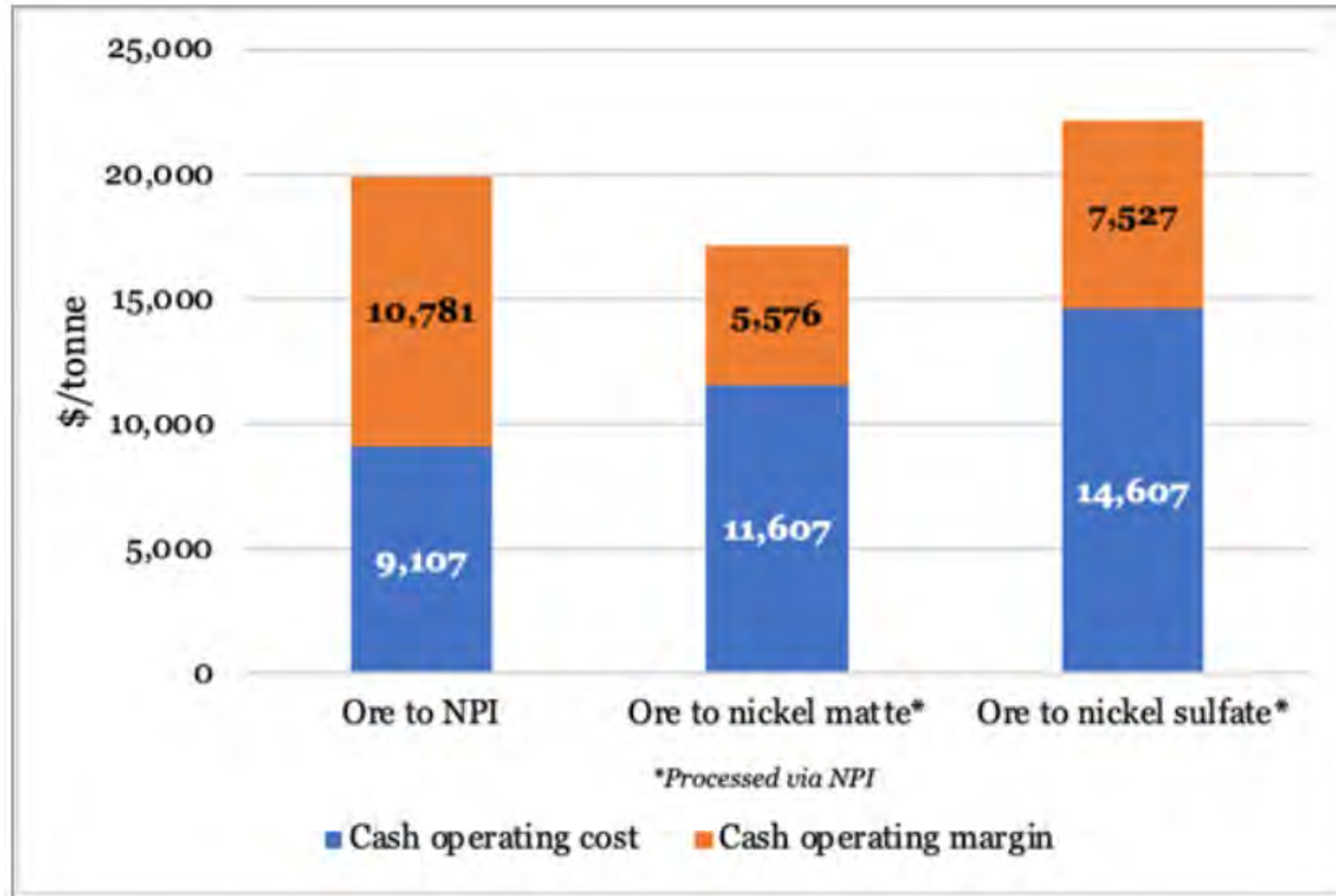
Note that sulfide ores typically are crushed, ground, floated to achieve concentrate and flash smelted to matte.

Red-dashed boxes capture strategies to process low-grade lateritic ores to battery grade nickel.



Sources: Mineral nomenclature from USGS, see endnote 4. UBS Research, from <https://www.kitco.com/commentaries/2018-09-13/Nickel-Laterite-s-Integral-Role-in-the-Coming-Nickel-Boom-Part-2.html>. For ore treatment processes, please see Monhemius, A. J., 1987, *Treatment of Laterite Ores of Nickel to Produce Ferronickel, Matte or Precipitate*, Imperial College, London, January, [https://www.researchgate.net/publication/291165654\\_Treatment\\_of\\_laterite\\_ores\\_of\\_nickel\\_to\\_produce\\_ferronickel\\_matte\\_or\\_precipitated\\_sulphide](https://www.researchgate.net/publication/291165654_Treatment_of_laterite_ores_of_nickel_to_produce_ferronickel_matte_or_precipitated_sulphide) and Davenport, W. and Moats, M., 2014, *Nickel and Cobalt Production, Treatise on Process Metallurgy: Industrial Processes*, <https://mail.google.com/mail/u/0/?tab=rm#inbox/FMfcqzGllVqqdbQTprVMRmTWrpNSRjfp?projector=1&messagePartId=0.4>. For processing costs, please see Sappor, J., 2021, *Commodity Monthly – Nickel April 2021*, S&P Global Market Intelligence, April, accessed via license. For global first-use figures, please see Nickel Institute, 2021, *About Nickel and Its Applications*, <https://nickelinstitute.org/about-nickel-and-its-applications/>.

# Processing Costs, Cash Margins

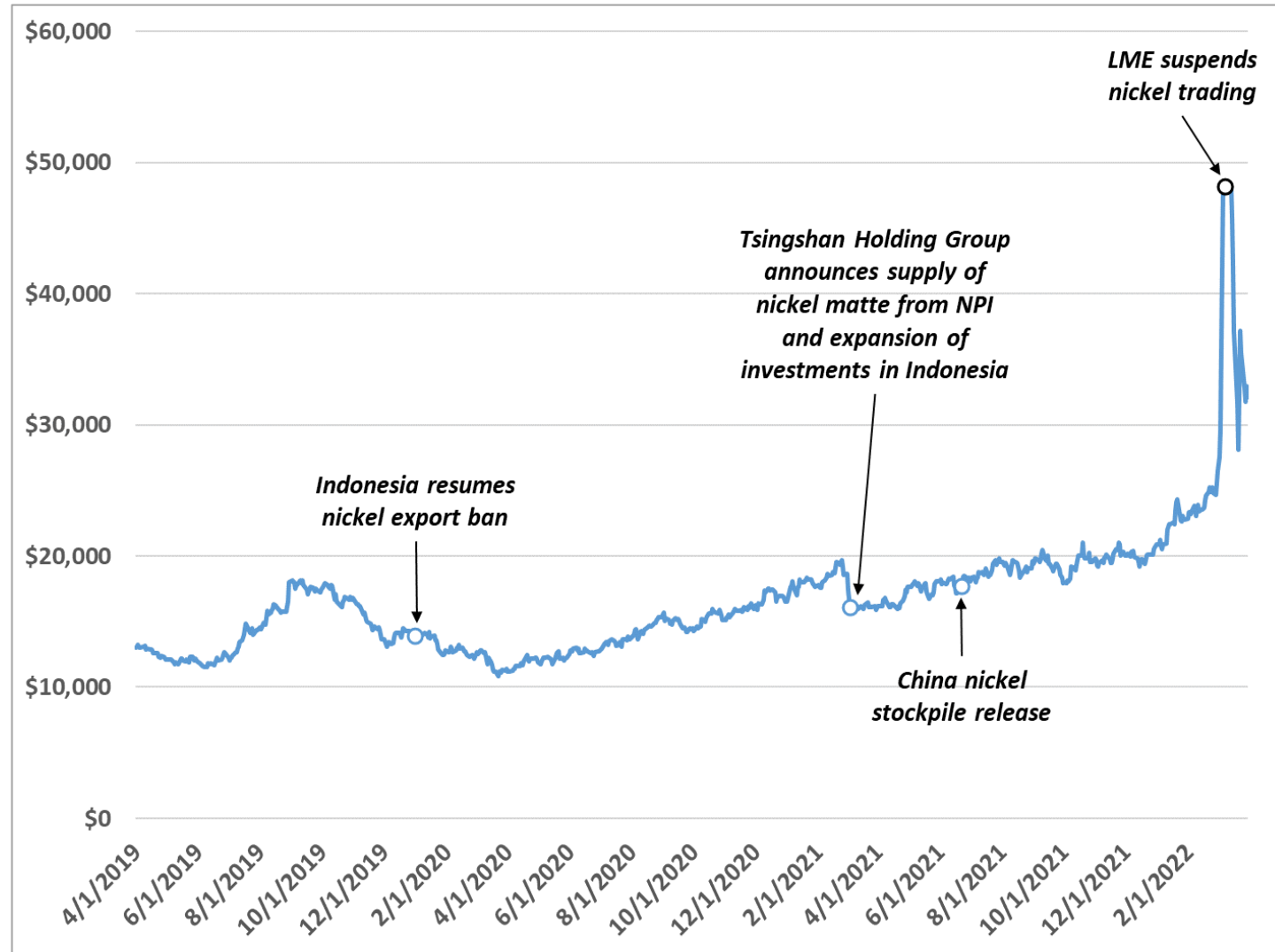


*SPG analysis, used with permission.*



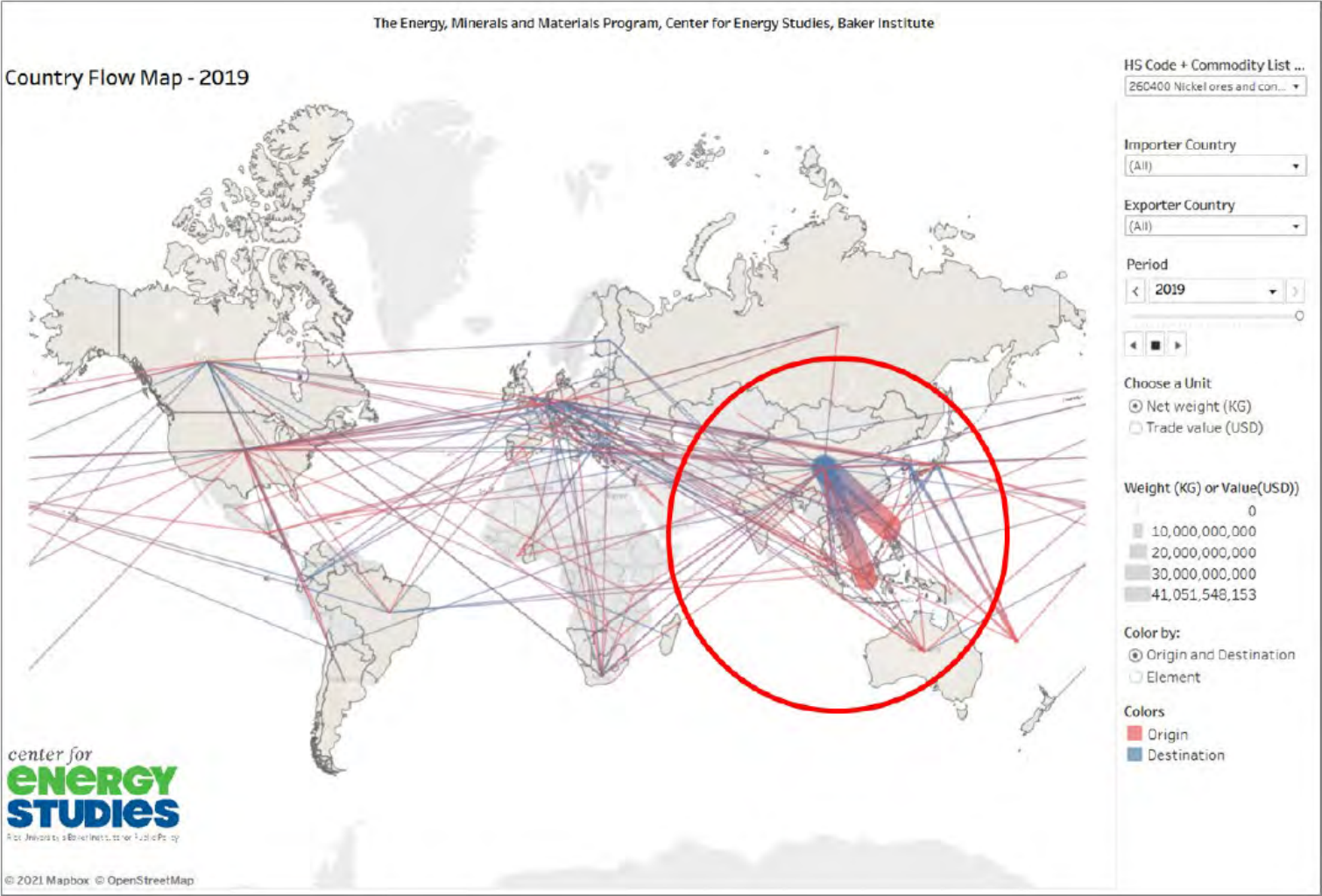


# Closer Look at Trading Adventures



Author using SPG for LME price, accessed via license.

# Geopolitics for Everyone



<https://www.bakerinstitute.org/global-minerals-trade-dashboard>

# Suggested Resources and Links

- M. Michot Foss, [Future Minerals Heartland](#), Future Minerals Forum 23, Riyadh, Saudi Arabia
- M. Michot Foss, J. Koelsch, [China's Rare Earths Dominance](#)
- M. Michot Foss, J. Koelsch, [What China's control of nickel means for the energy transition](#)
- CES China Energy Map <https://www.bakerinstitute.org/chinas-energy-infrastructure/>
- CES minerals production/trade visualizations <https://www.bakerinstitute.org/energy-minerals/>
- M. Michot Foss, [testimony](#) before the U.S. Senate Committee on Energy & Natural Resources, March 10, 2022,.
- M. Michot Foss, [testimony](#) before the U.S. House Subcommittee on Energy on the CLEAN Future Act, May 5, 2021
- M. Michot Foss, [recommendations](#) to the Biden Administration
- M. Michot Foss, M. Moats, K. Awuah-Offei, [G20 technical brief](#) on future minerals pathways
- R.A. Meidl, M. Michot Foss, J. Li, forthcoming, [A Call to Action for Recycling and Waste Management Across the Alternative Energy Supply Chains](#)
- R.A. Meidl, recommendations to the Biden Administration [Waste Management and the Energy Transition](#)
- R.A. Meidl, [Measuring the True Cost](#) of Sustainability: A Case Study in a Green Energy Approach
- R.A. Meidl, [Smart policy](#) and innovative technologies, like advanced recycling, will deliver on climate and sustainability goals
- G. Collins and A. Erikson, [China's Climate Cooperation Smokescreen](#), [U.S.-China Competition Enters the Decade of Maximum Danger](#)
- G. Collins and M. Michot Foss, [Want to Derail the Energy Transition? Take Fossil Fuels Out of the Mix](#), [Energy Transition Valley of Death](#)