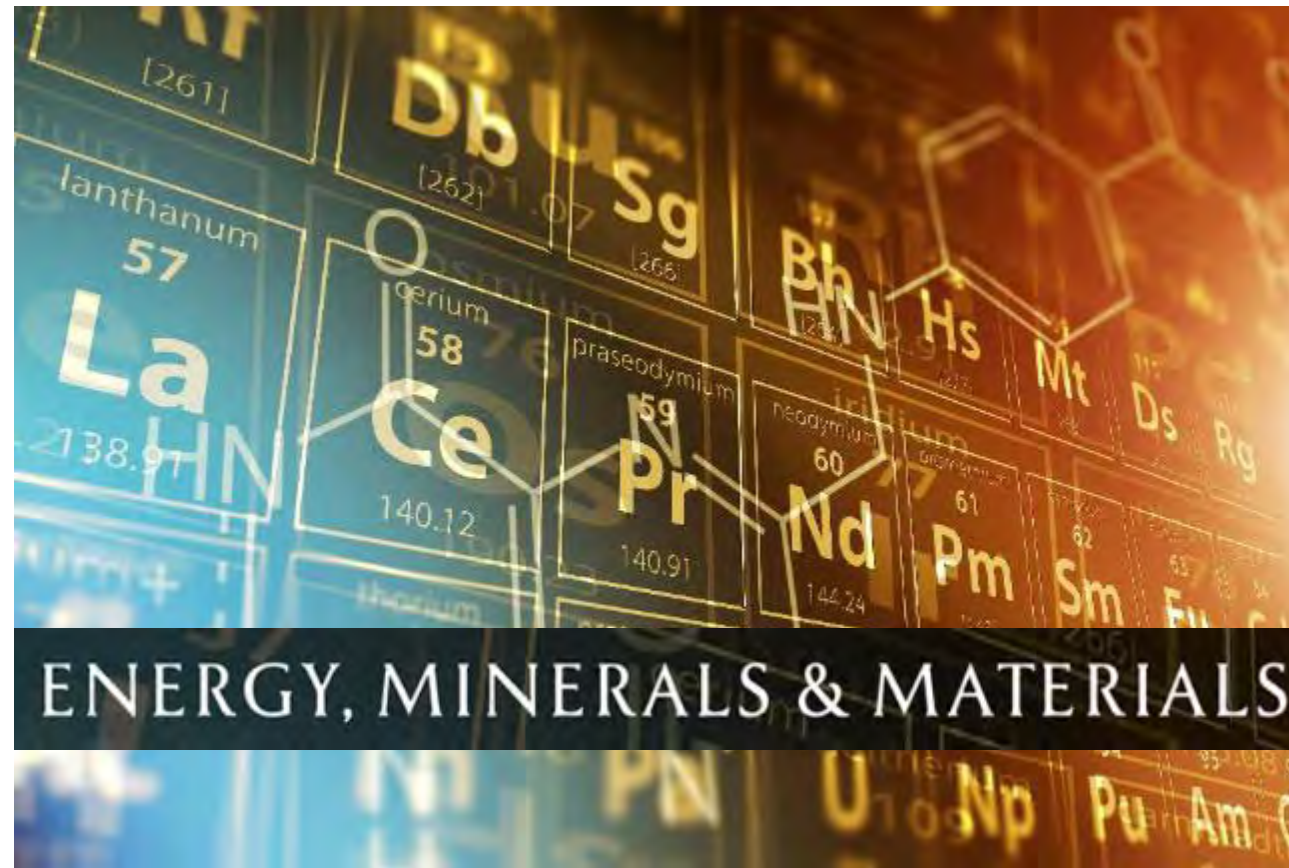


# Minerals, Materials, Energy Security



***Michelle Michot Foss, Ph.D.***

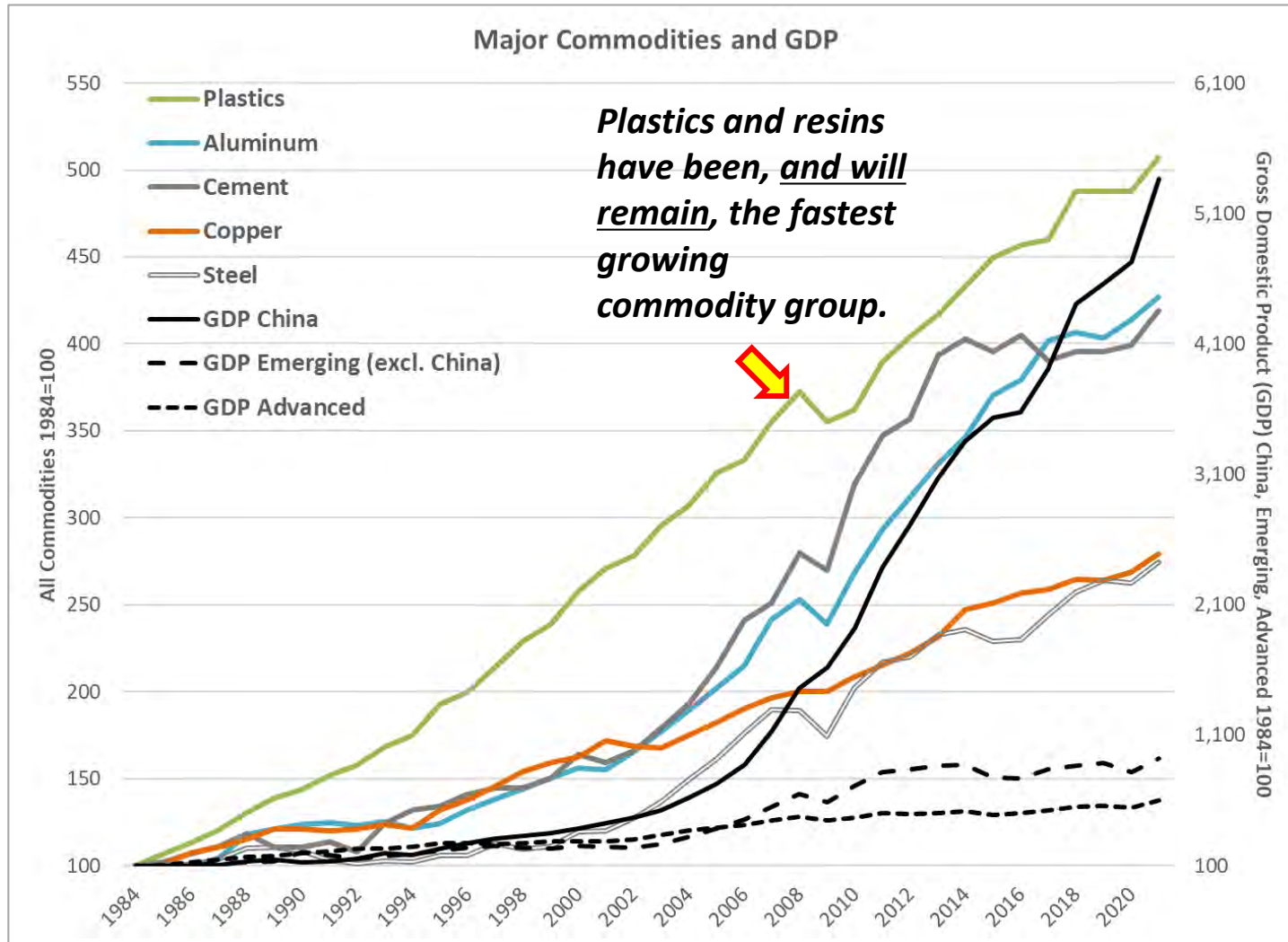
***GRIPS 19<sup>th</sup> GiST Seminar, April 28, 2023***



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

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

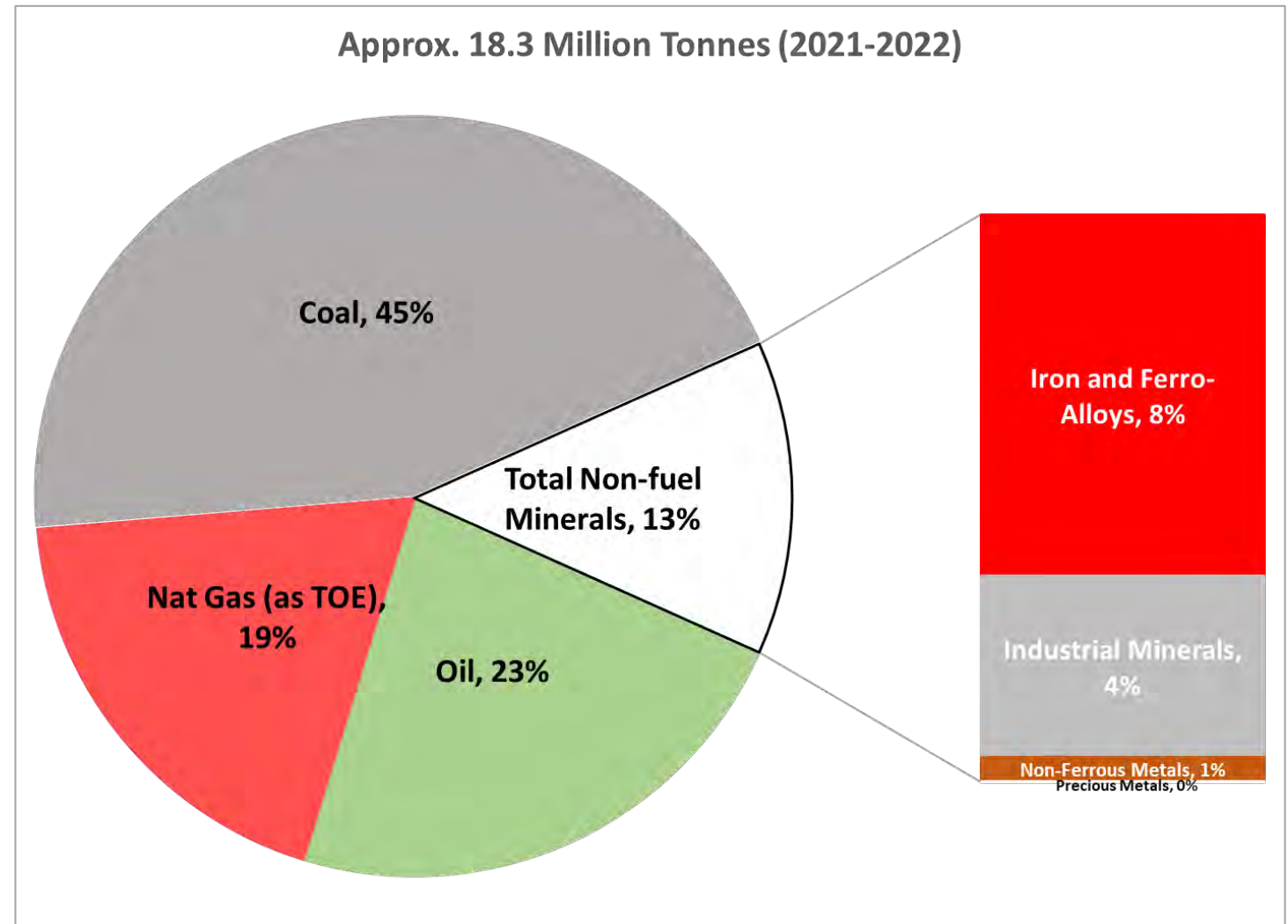
# Do we have “enough”? It depends!



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

# Fuel and Non-fuel Minerals Output

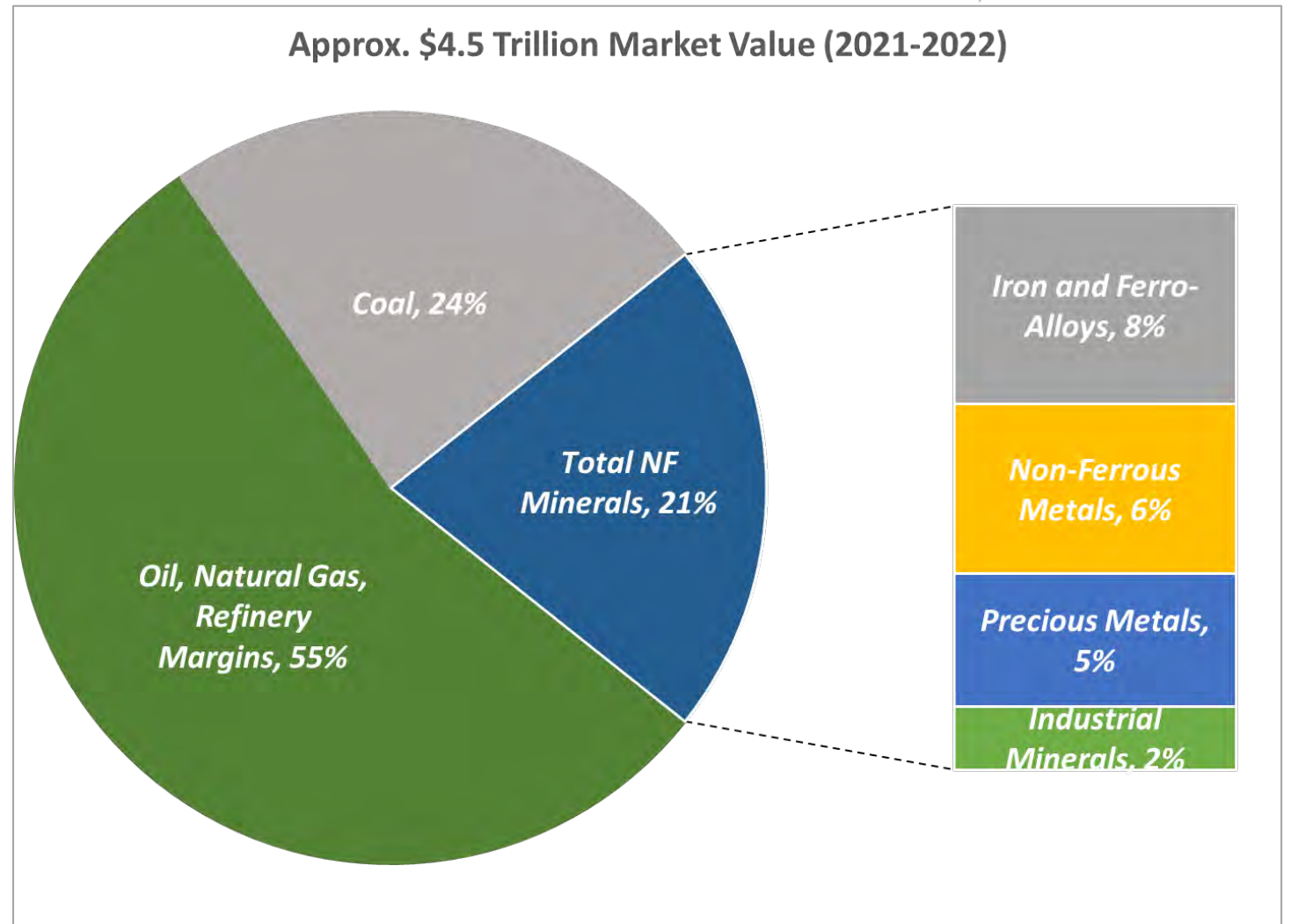
- In “net zero” scenarios both the energy equivalent **AND** intrinsic energy storage attributes of fossil fuels must be replaced.
- Battery metals and materials **ONLY** provide energy storage.
- Energy must be provided from other sources in the equivalent of fossil fuels commitments **IF** fossil fuels 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

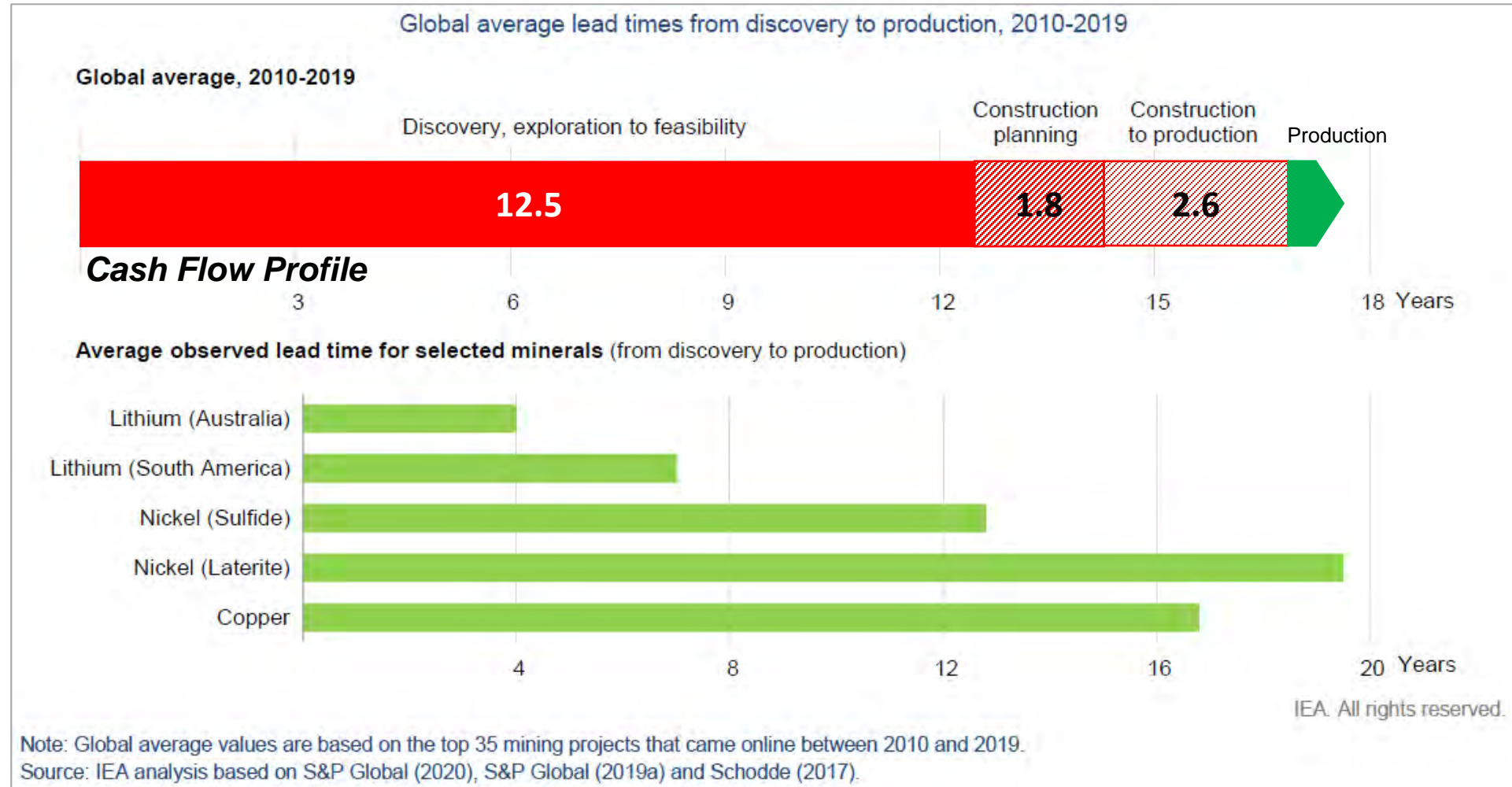
- Much of mining industry cash flow derives from...**COAL!**
- The total value of all mined non-fuel minerals is **21%** of the total market value of fuel and non-fuel commodities together, based on 2021 production and 2022 market values of ~\$3.5 trillion.
- Miners and sovereigns aspire to replace oil 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.*

# 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>



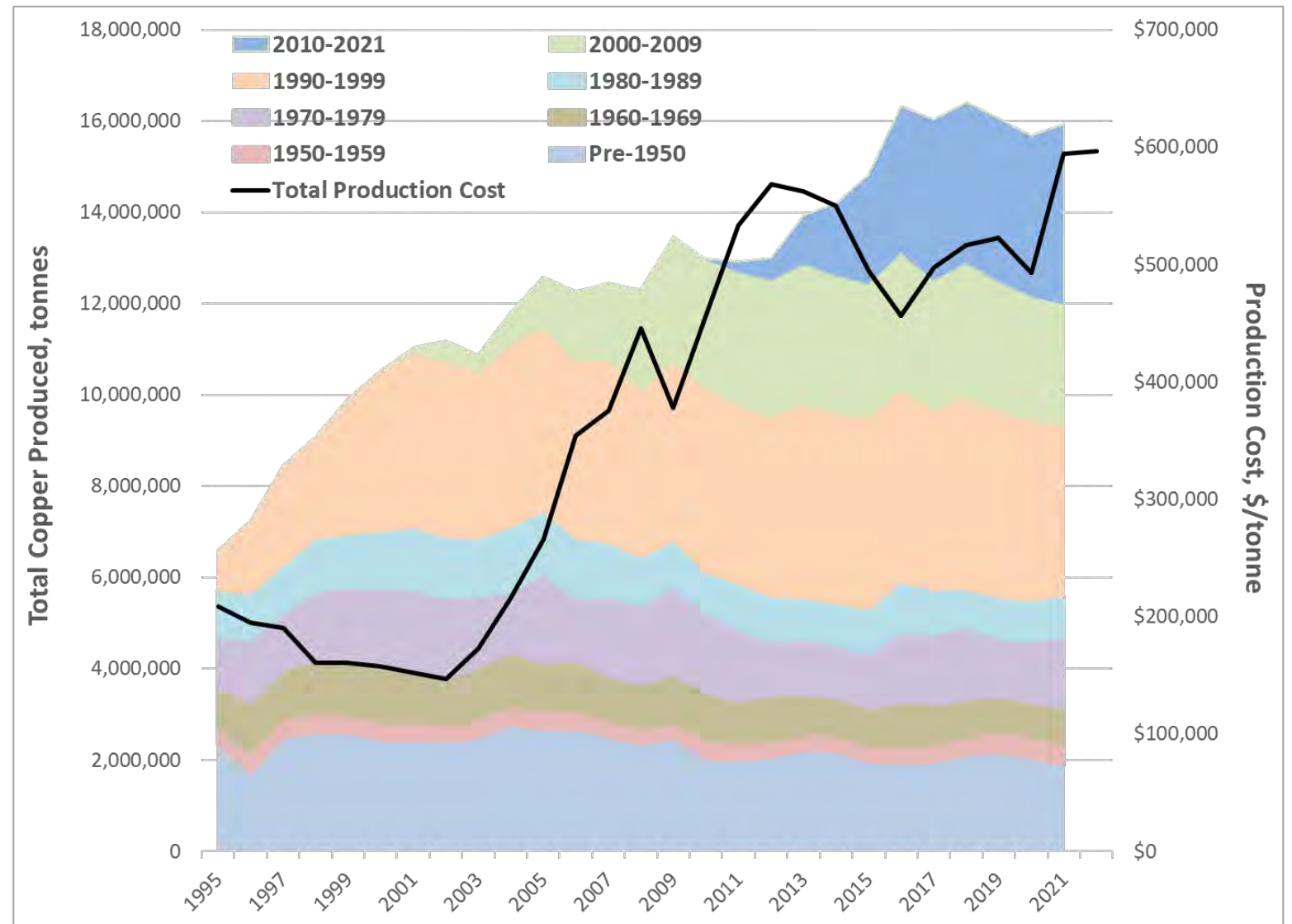
IEA, <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>  
Note – cash flow profile modified from IEA original graphic by author.

# U.S. Nevada Example

[https://www.energy.senate.gov/hearings/2022/3/  
full-committee-hearing-on-domestic-critical-  
mineral-supply-chain](https://www.energy.senate.gov/hearings/2022/3/full-committee-hearing-on-domestic-critical-mineral-supply-chain)

# Challenge of Sustaining Supply: Copper Example

- 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.



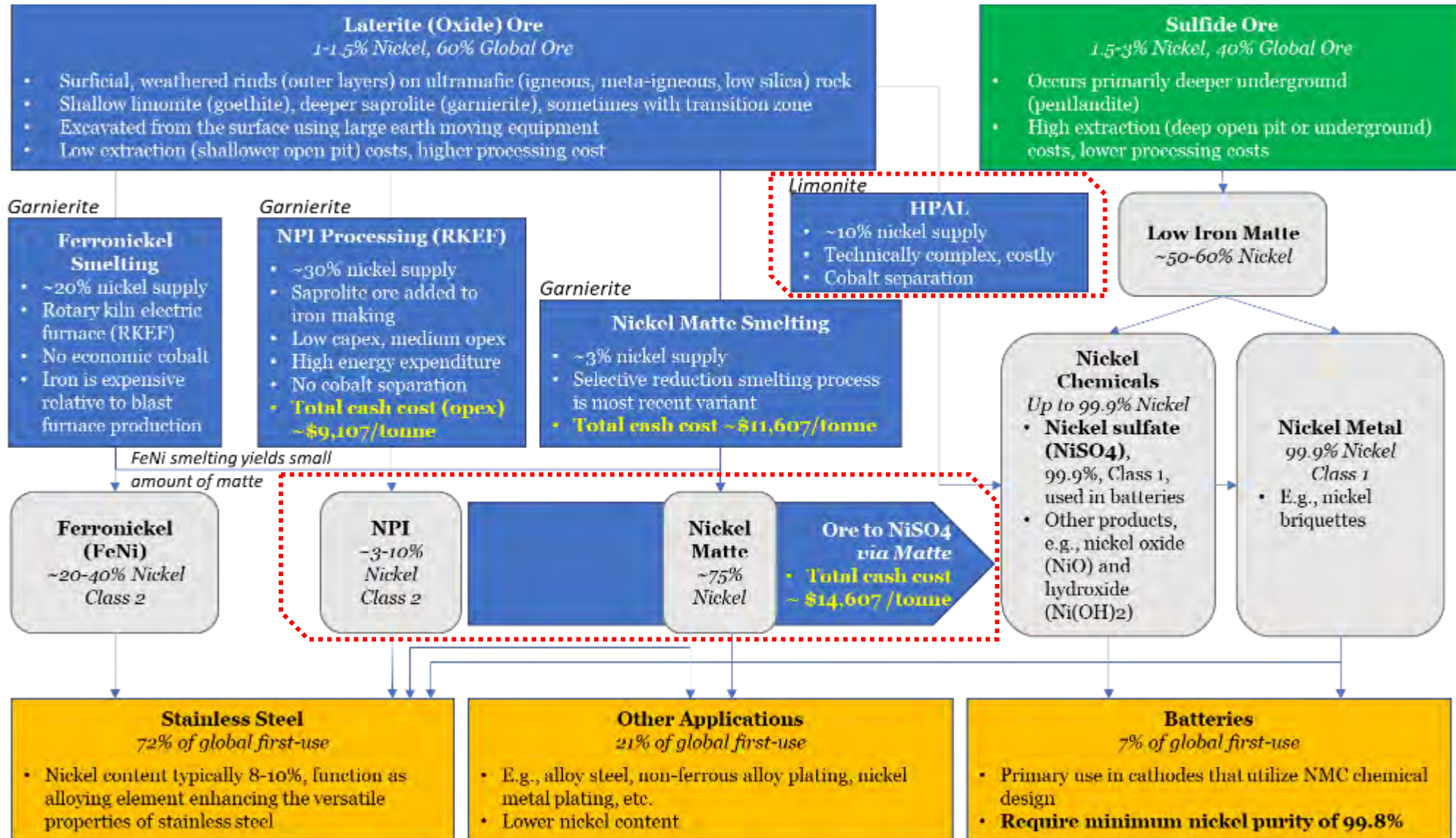
MM Foss using SPG, accessed via license. Work in progress.



# 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/>.



# 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"



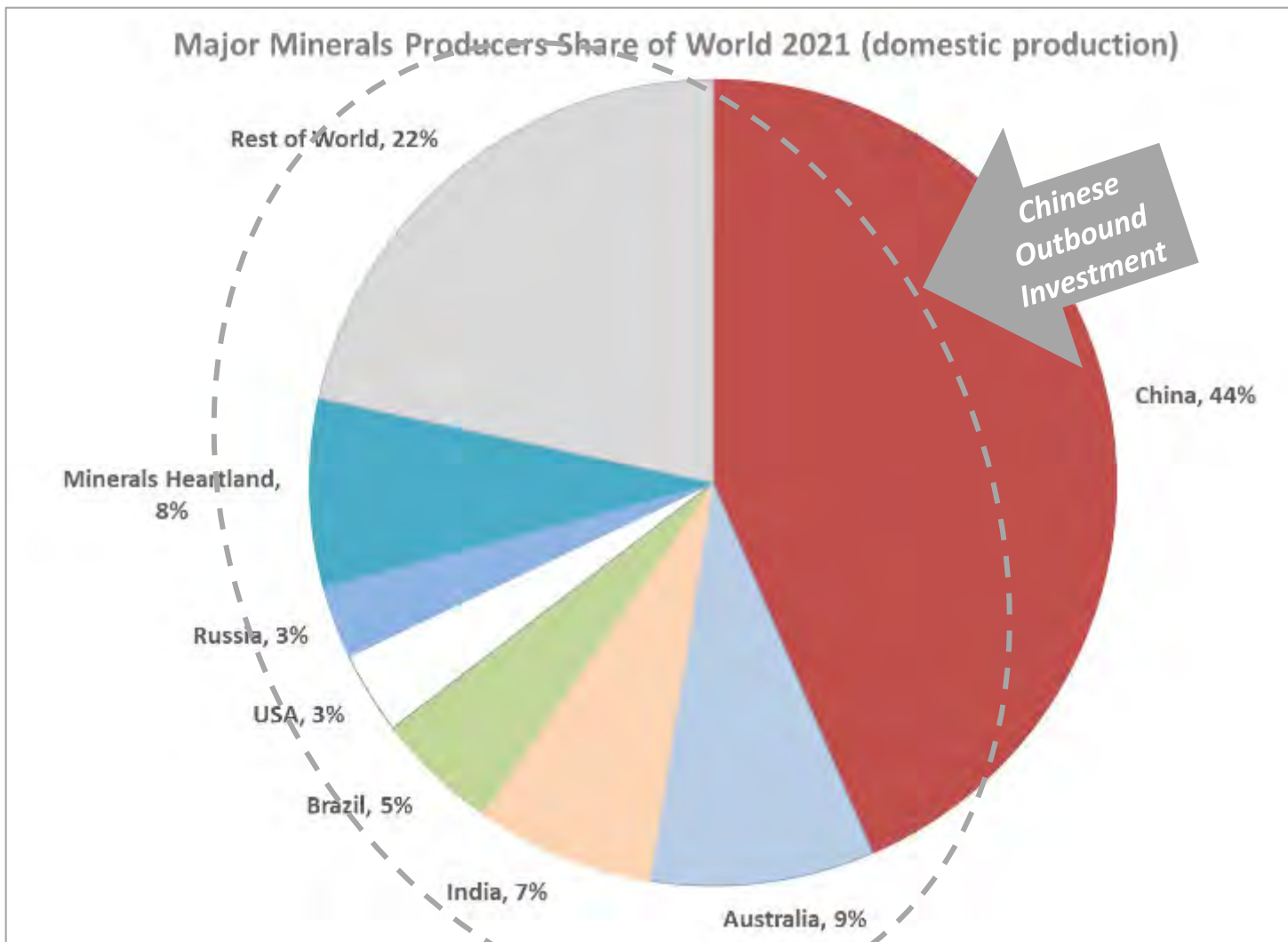
Dec. 1984



# 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.....

# 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.

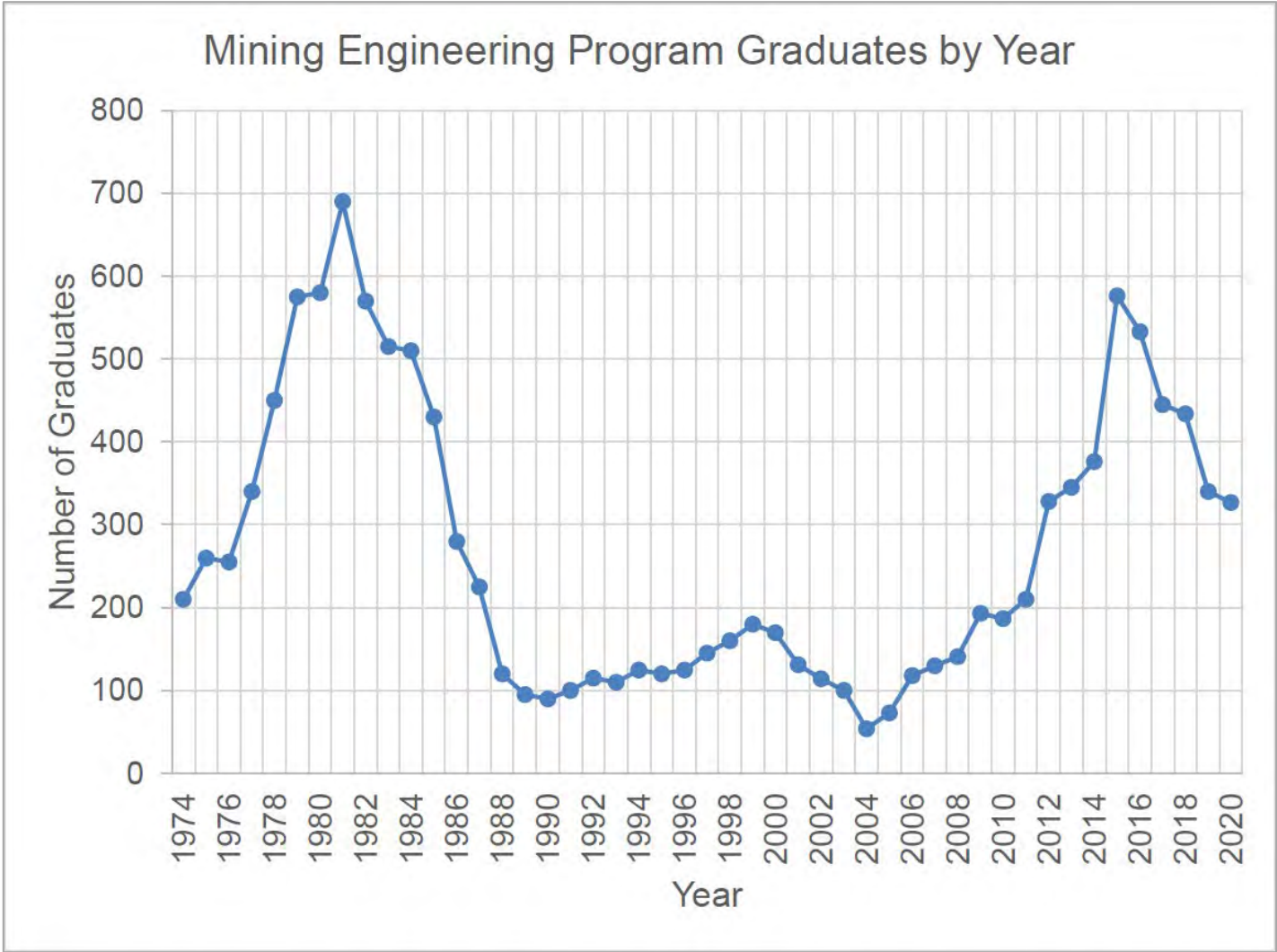
<https://www.bakerinstitute.org/sites/default/files/2022-04/import/research-paper-nickel-041122.pdf>

# 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

# U.S. Enrollments Follow Prices



<https://www.smenet.org/What-We-Do/Technical-Briefings/Maintaining-the-Viability-of-U-S-Mining-Education>

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