Nickel and the Energy Transition; current nickel resources, reserves, supply and demand and implications for the future of the nickel sector

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We acknowledge that the University of Nevada, Reno is situated on the traditional homelands of the Numu (Northern Paiute), Wašiw (Washoe), Newe (Western Shoshone), Nuwu (Southern Paiute) peoples.

Introduction

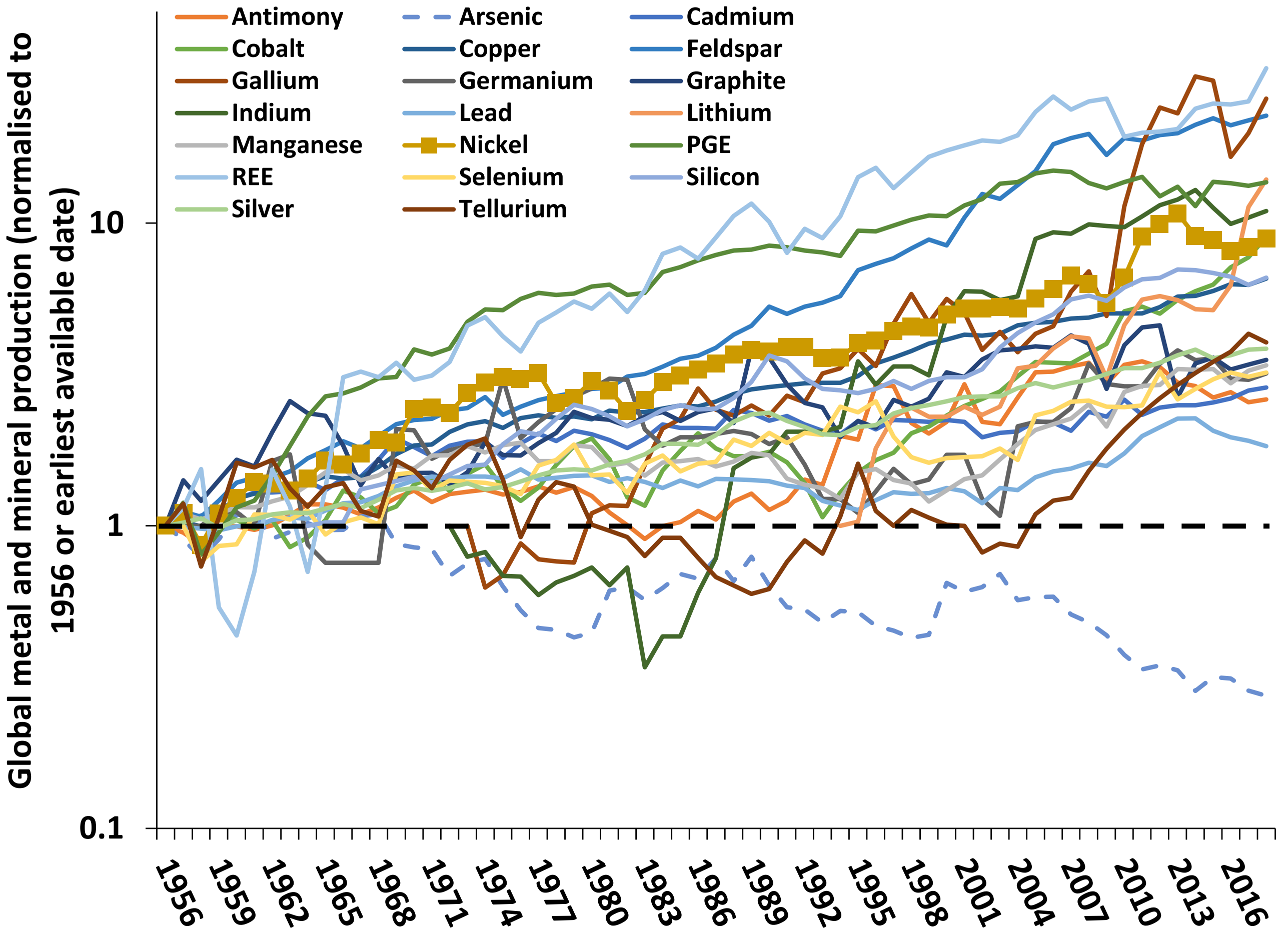
- Nickel is fundamentally important to modern life and society
- Crucial for the production of stainless steel, specialty alloys, electroplating, battery production, and other uses.
- Global nickel demand is expected to soar as the world transitions to a low- to zero-CO_2 and carbon neutral energy and transport future but timing of demand and supply changes uncertain
- The future will necessarily involves the greater use of batteries for energy storage associated with renewable energy systems; hence almost certainly greater demand for nickel
- Why sometimes called the Devil’s metal? Saxon miners in Germany found rich ores (*kupfernickel* or Devil’s copper) that didn’t produce then-valuable metals but instead yielded nickel

Future controls on nickel demand and supply?

- World Bank estimates suggest global carbon neutral energy generation and storage and transport demand for nickel by 2050 will equal nearly 100% of current production; need to double the amount of nickel we mine?
- This means that understanding the current nickel market and known nickel resources and reserves (i.e., current and likely future sources of this metal) are key to enabling this energy transition
- Includes likely environmental, social, and governmental (ESG) challenges that may prevent nickel project development or hinder current operations – key challenge for the entire minerals industry
- Transition driven by climate change mitigation but also (and perhaps more by) consumer and investment spending and demand
- First, some wider context

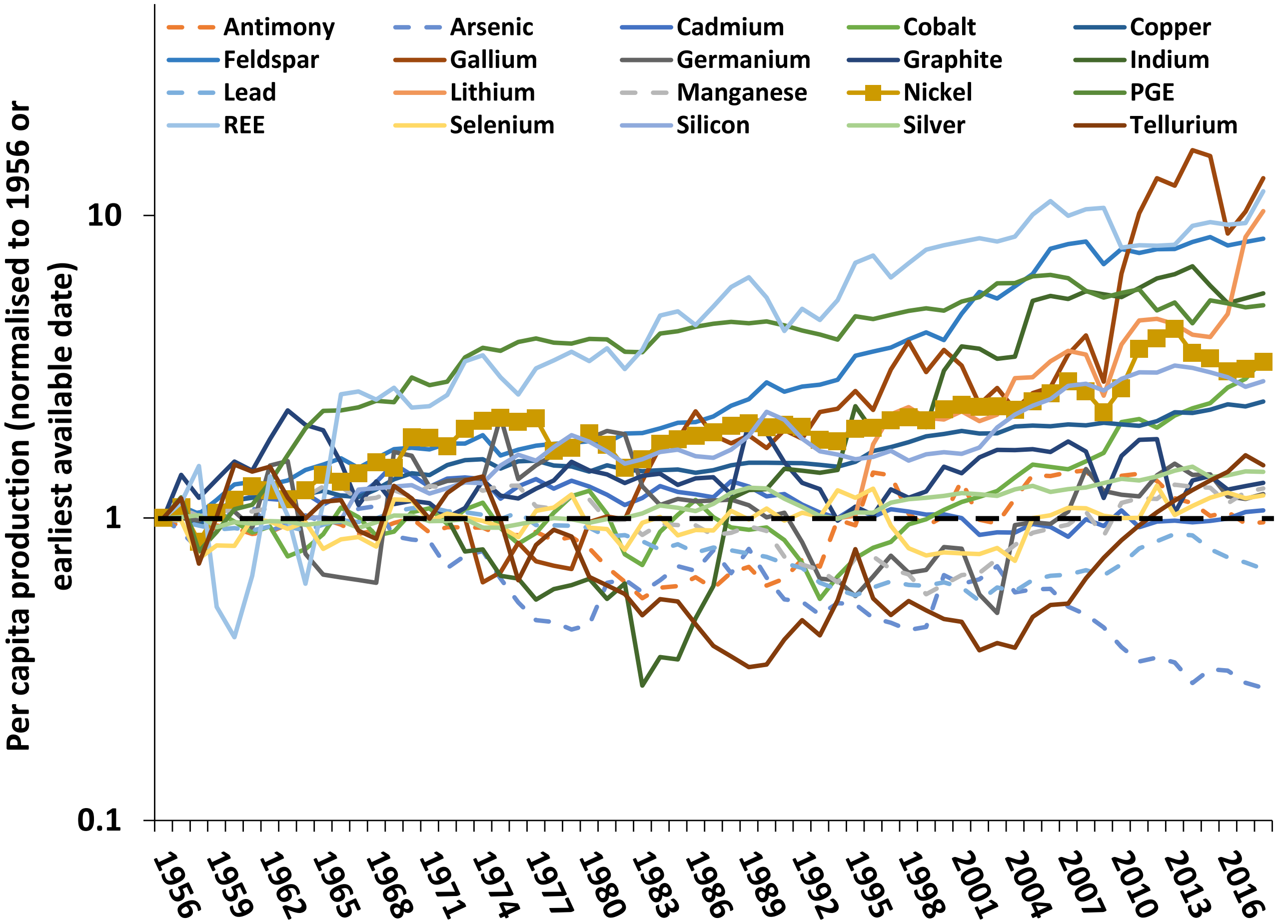
Modern technologies have become more mineral intensive

We mine more metals than ever before; ~10.5 times more Ni in 2022 than in 1956



Jowitt, 2022

Not just totals but per capita (barring Pb, Sn, W); 3.8 times more Ni mined per person in 2022 than in 1956, even with increased recycling

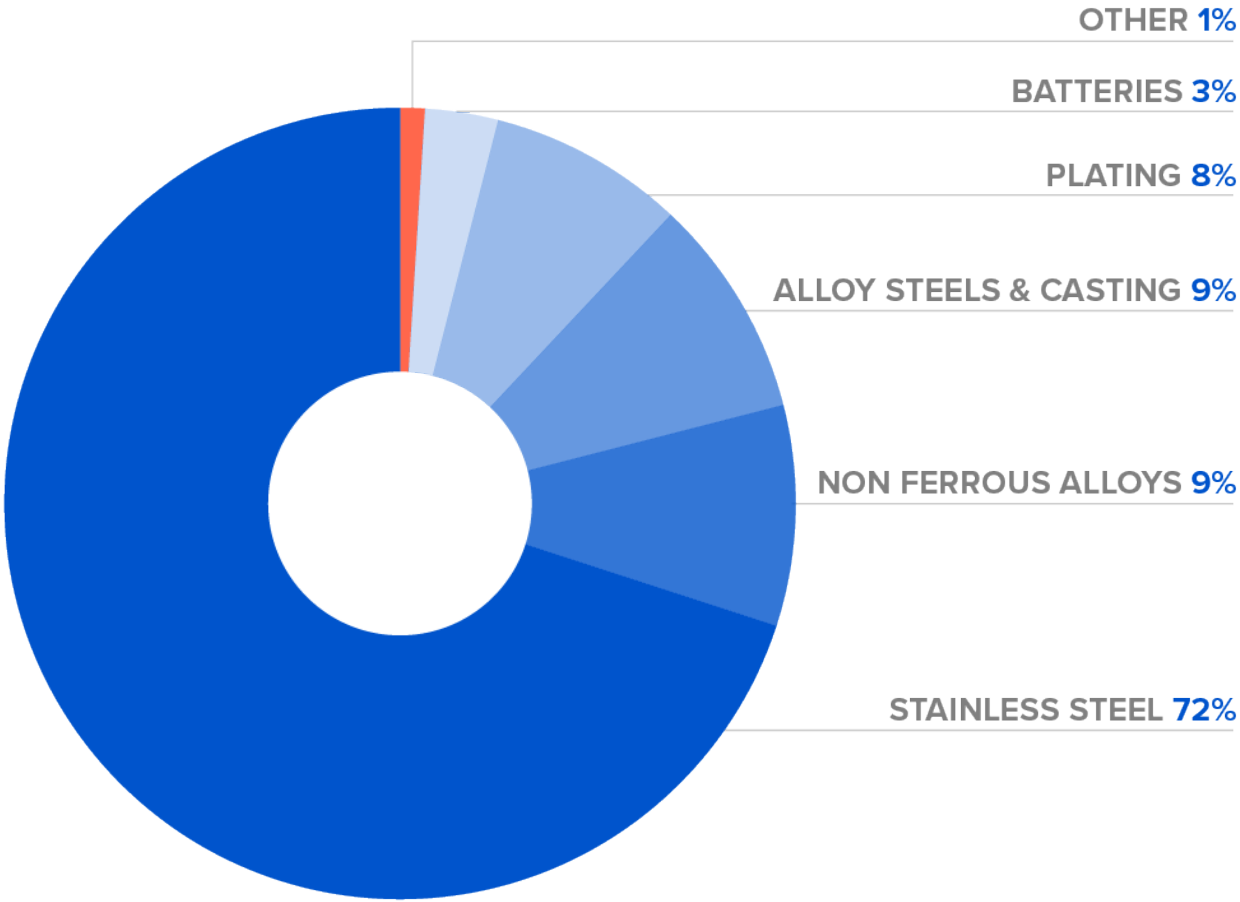


Jowitt, 2022

So what about future nickel demand?

- Before we get into current resources and reserves, need to understand current drivers of demand
- Global movement towards low- and zero CO_2 energy generation, storage and transport
- Driven by two things; climate change mitigation and consumer and investment demand and spending.
- Implications for nickel?

Initial uses of mined nickel

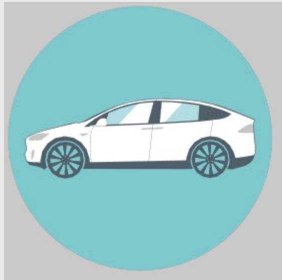


Increased use of nickel in low/zero CO_2 energy storage, generation, transport…

"Our cells should be called Nickel-Graphite, because primarily the cathode is nickel and the anode side is graphite with silicon oxide… [there's] a little bit of lithium in there, but it's like the salt on the salad" - Elon Musk, CEO Tesla

LI-ION BATTERIES

Nickel plays a crucial role in lithium-ion battery chemistries used to power electric vehicles, medical devices and cordless power tools as well as store renewable energy.

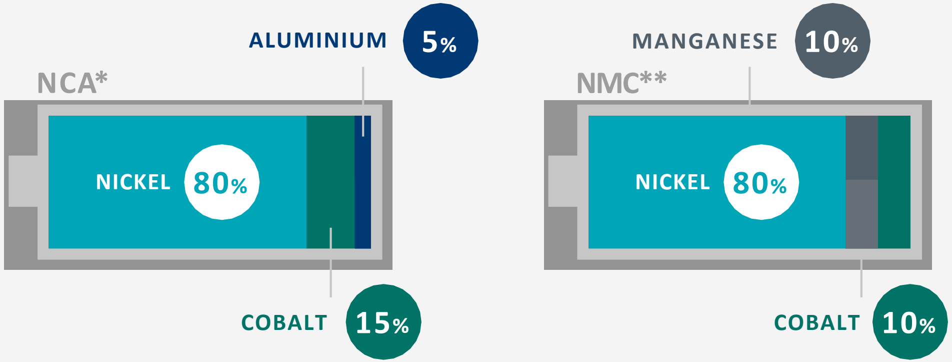


TODAY'S BATTERY OPTIONS

Lithium compounds are combined with other materials in order to create Li-ion batteries.

Two of the commonly used Li-ion battery chemistries contain nickel.

CATHODE COMPOSITION:

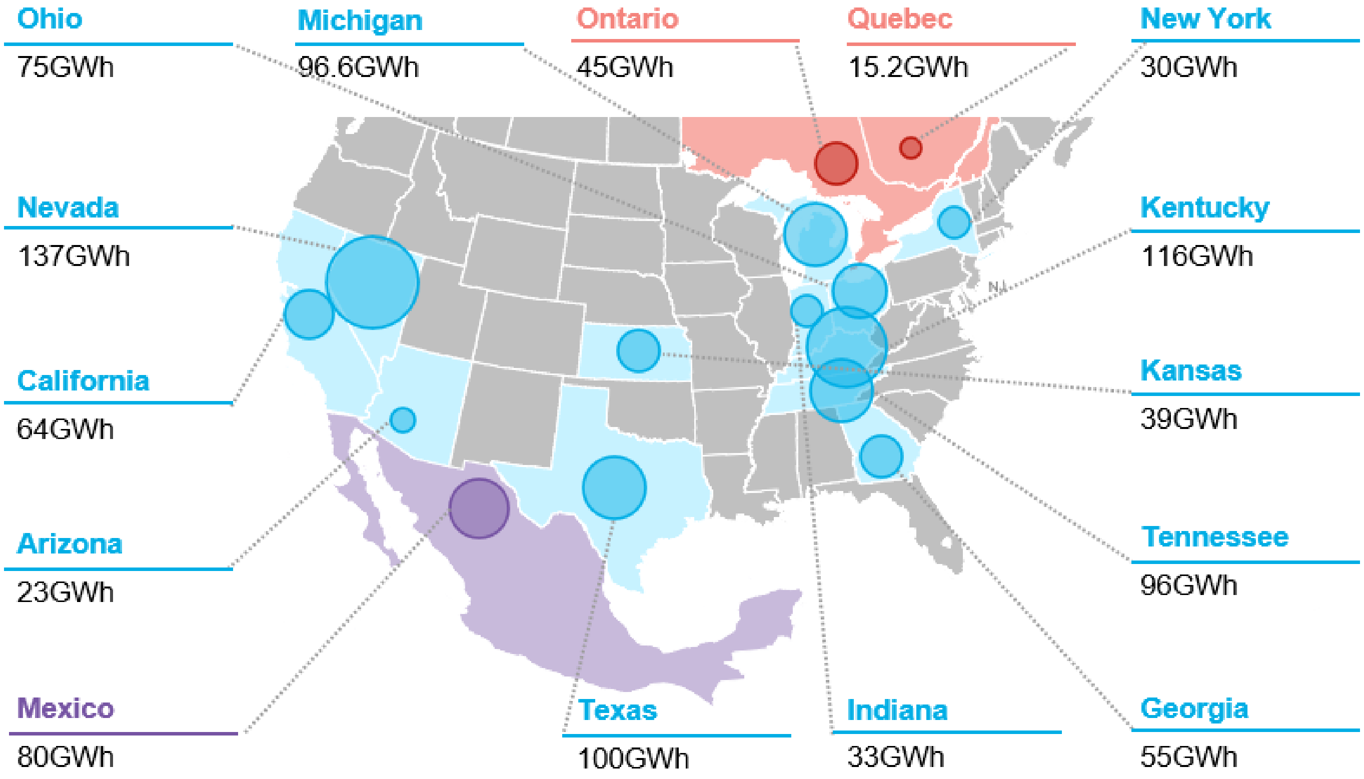


*NCA: Nickel Cobalt Aluminium
**NMC: Nickel Manganese Cobalt

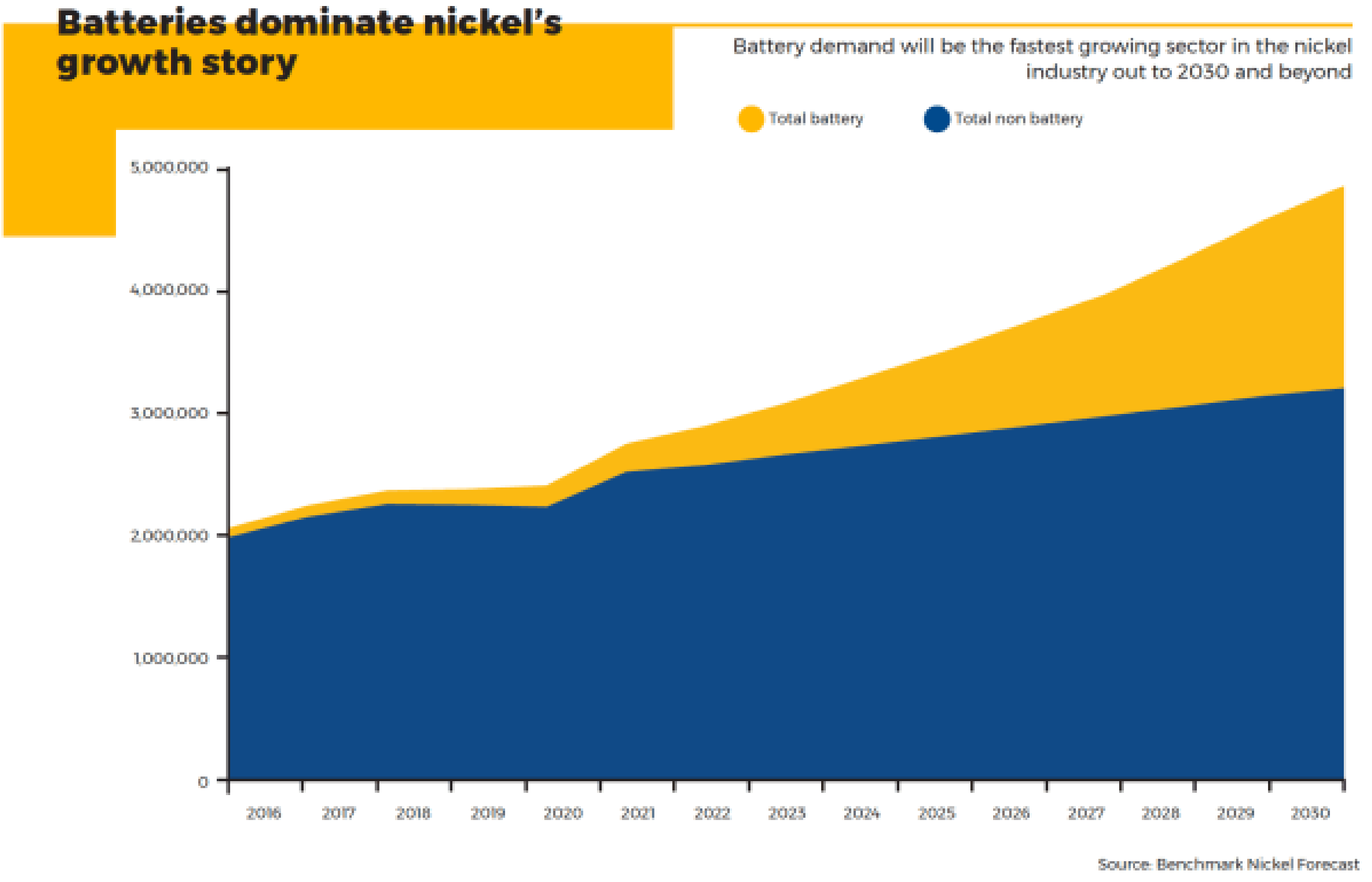
One example; Sparks Gigafactory, Nevada

- Gigafactory has a capacity of 35 GWh of cells per year; equivalent to 500,000 Teslas but also used in home energy storage
- 35 GWh of NMC-811 batteries needs ~3,885t lithium, ~3,290t cobalt, ~26,250t nickel, ~3,080t manganese, and a lot of graphite
- Global nickel production in 2022 estimated to be 3.3 Mt; a facility of this size producing NMC-811 batteries would consume ~0.8% of global nickel production; proposed NMC-955 even more
- 300 Gigafactory-type developments completed, underway or planned…

North American planned and developed battery capacity

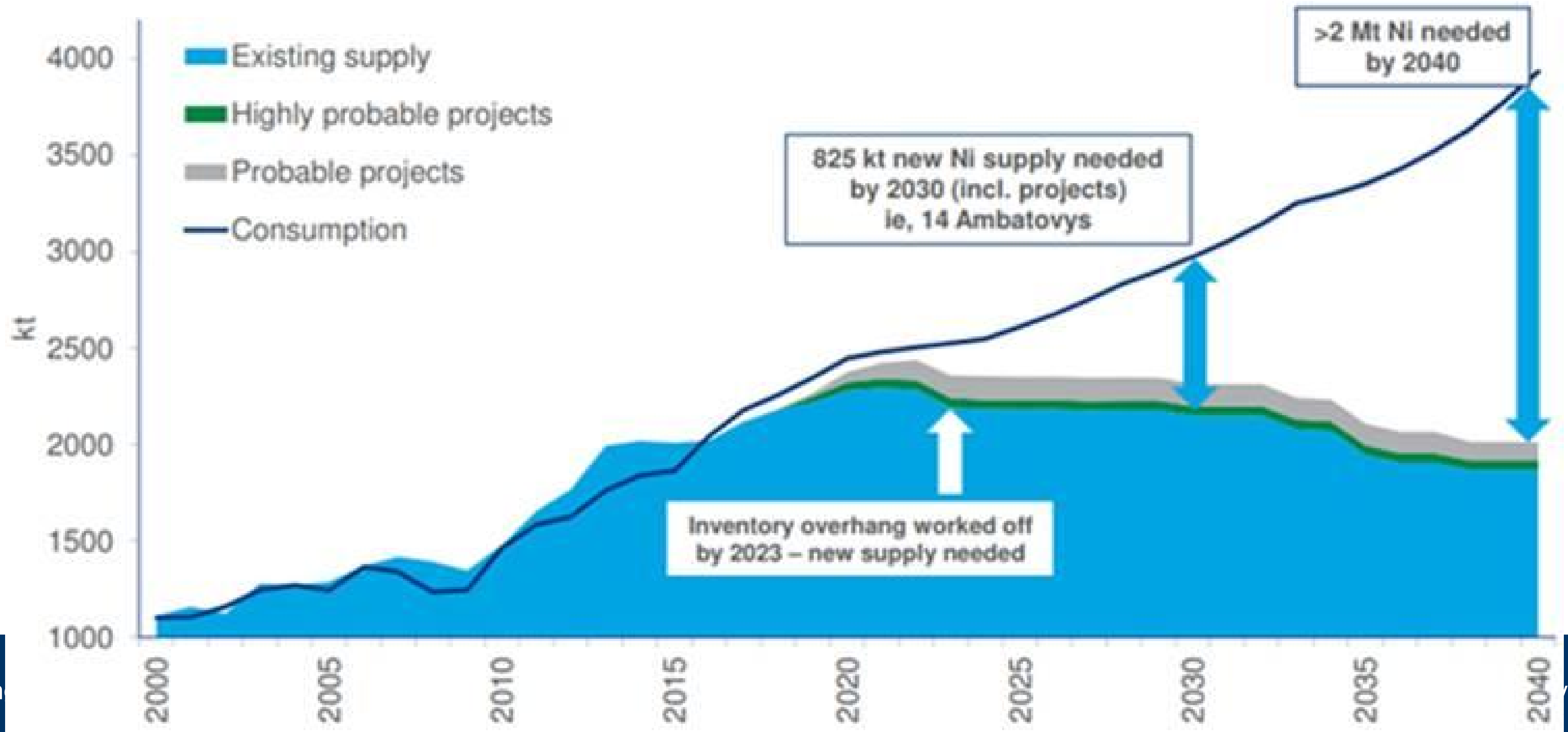


Batteries are going to be a major demand driver

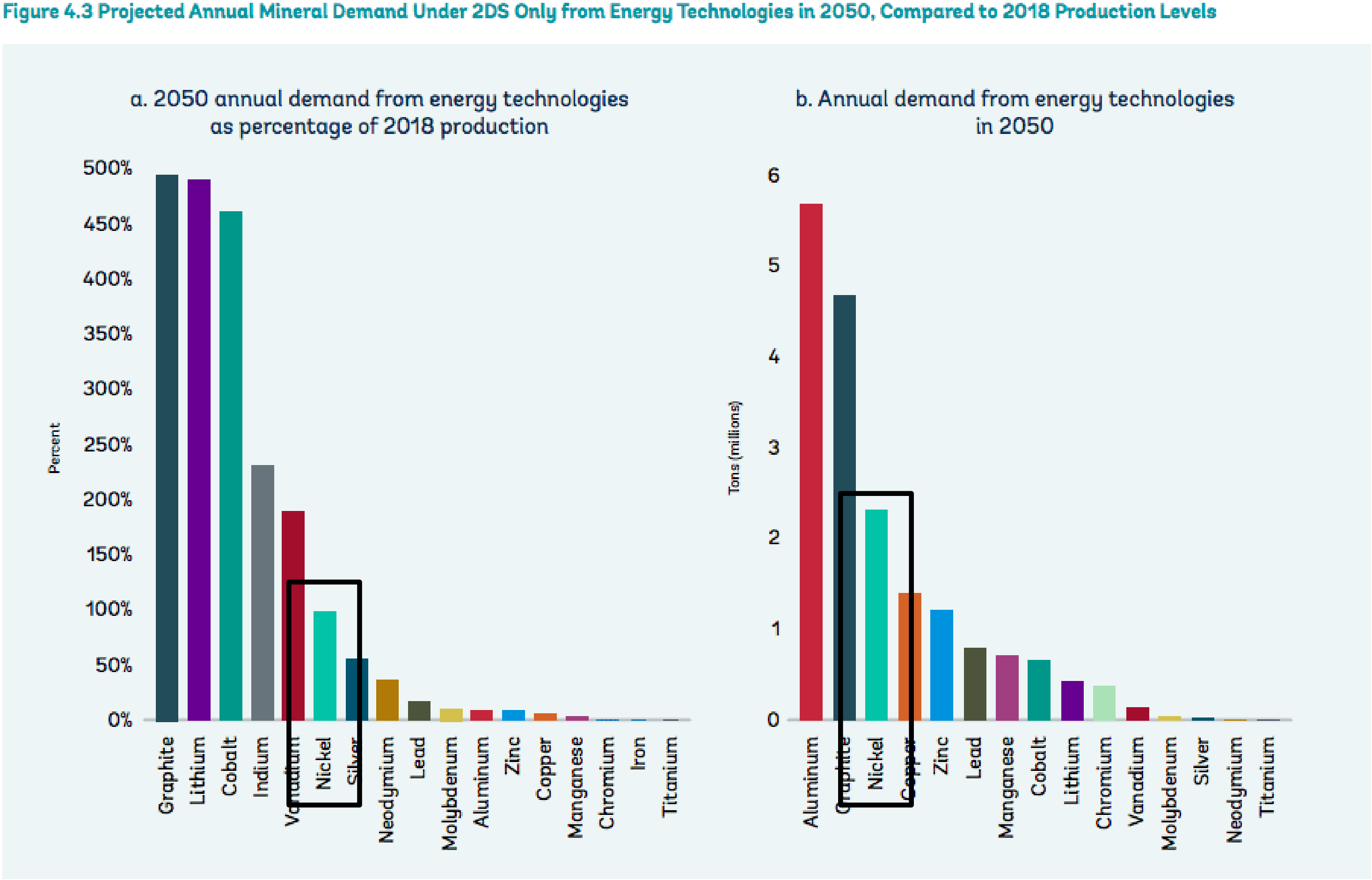


Nickel demand-supply scenario; but is this realistic?

- Based on current reserves and production; not always a good basis given resources and reserves can expand with time (e.g. 3.3 Mt of production in 2023); see later slides



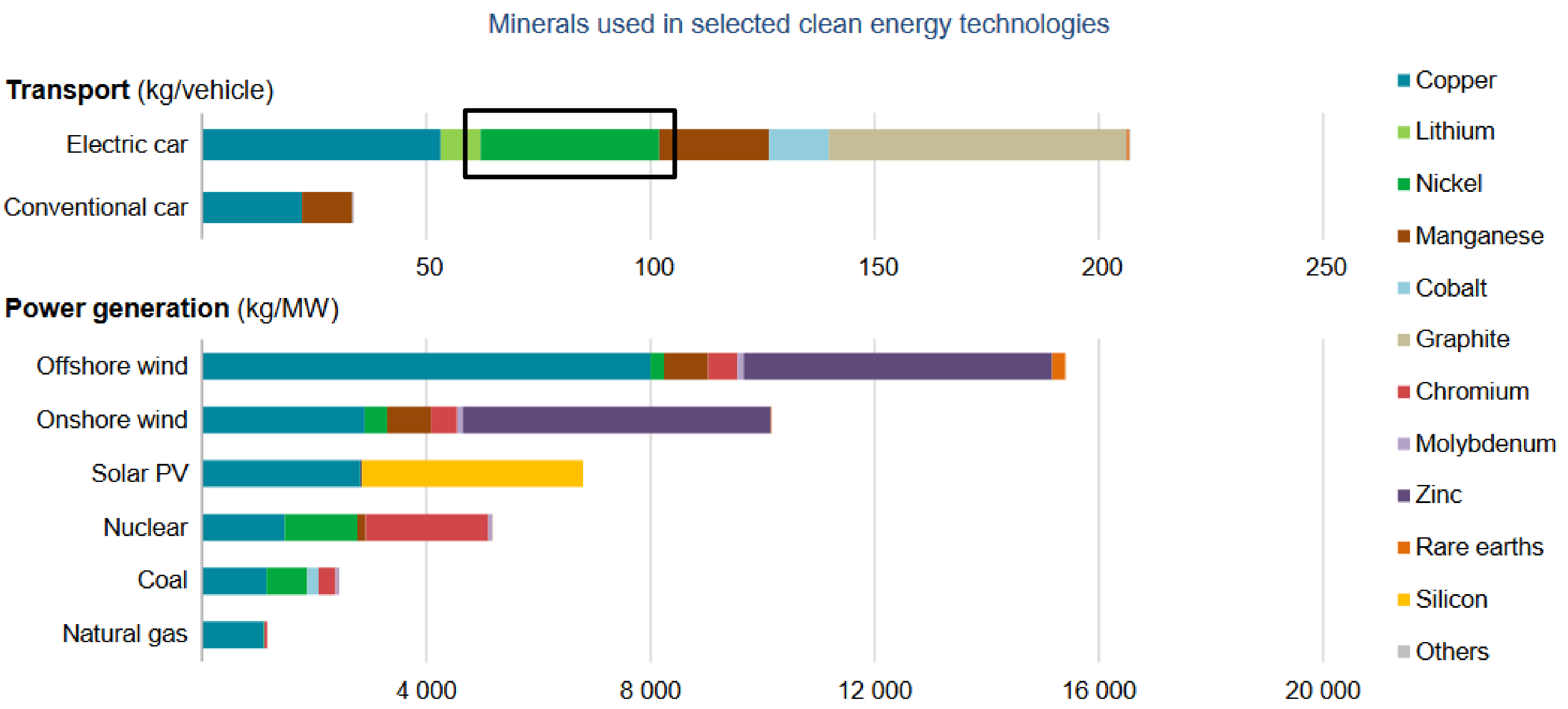
Increased demand for metals and mining as a result of green technology - energy



Demand… note that the central and right columns are from energy tech **ALONE**

Mineral	2018 annual production (Tons, thousands) [a]	2050 projected annual demand from energy technologies (Tons, thousands)	2050 projected annual demand from energy technologies as percent of 2018 annual production
Aluminum	60,000	5,583	9%
Chromium	36,000	366	1%
Cobalt	140	644	460%
Copper	21,000	1,378	7%
Graphite	930	4,590	494%
Indium	0.75	1.73	231%
Iron	1,200,000	7,584	1%
Lead	4,400	781	18%
Lithium	85	415	488%
Manganese	18,000	694	4%
Molybdenum	300	33	11%
Neodymium	23 [b]	8.4	37%
Nickel	2,300	2,268	99%
Silver	27	15	56%
Titanium	6,100	3.44	0%
Vanadium	73	138	189%

Increased demand for metals and mining as a result of green technology

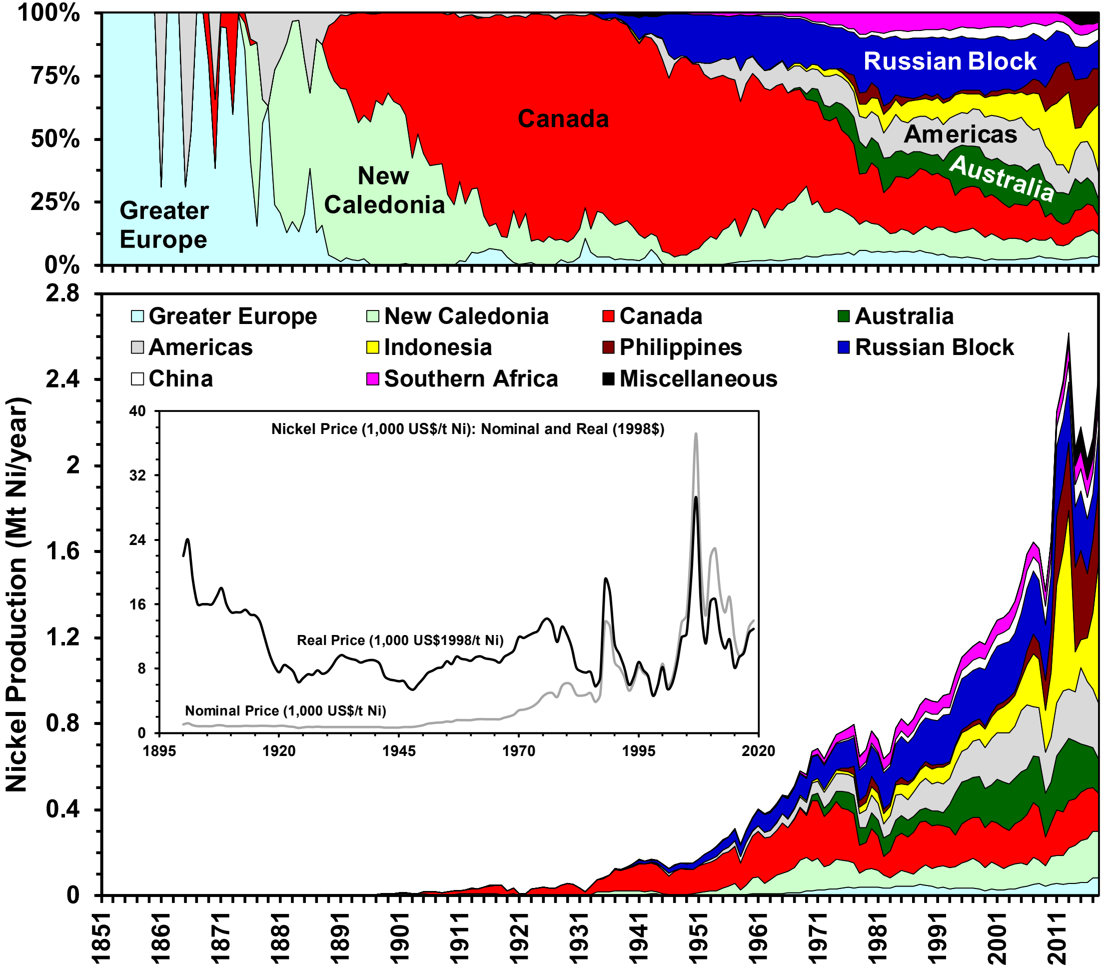


Notes: kg = kilogramme; MW = megawatt. Steel and aluminium not included. See Chapter 1 and Annex for details on the assumptions and methodologies.

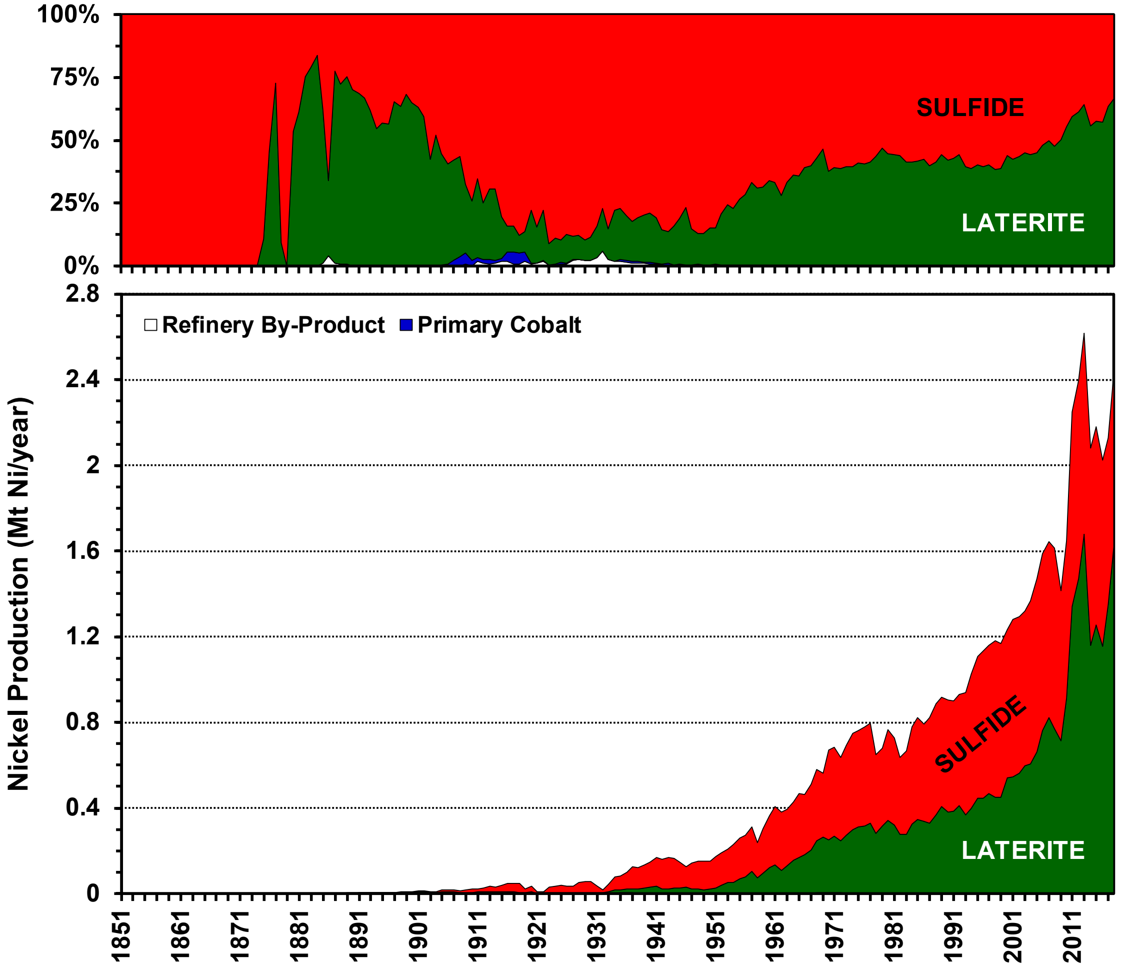
Global Nickel Resources and Reserves

- Can we meet a more than 100% increase in Ni mined production by 2050? If so, where is this going to come from?
- Understand the demand drivers, but need to examine the supply side
- Overview of global inventory of reported Ni resources and reserves for 2018, database and associated paper published in Economic Geology in 2022; email me if you want a copy…
- All classified by mineral deposit type; outlines the relative importance of the different mineral systems that are mined for nickel
- Majority of nickel has been and will continue to be sourced from nickel laterites and magmatic sulfide systems; ~50:50 now but laterites trending upward and ore grades generally decreasing in all deposit types
- Other deposits have been mined for nickel although production from these remains relatively small

Global Nickel production by country and pricing



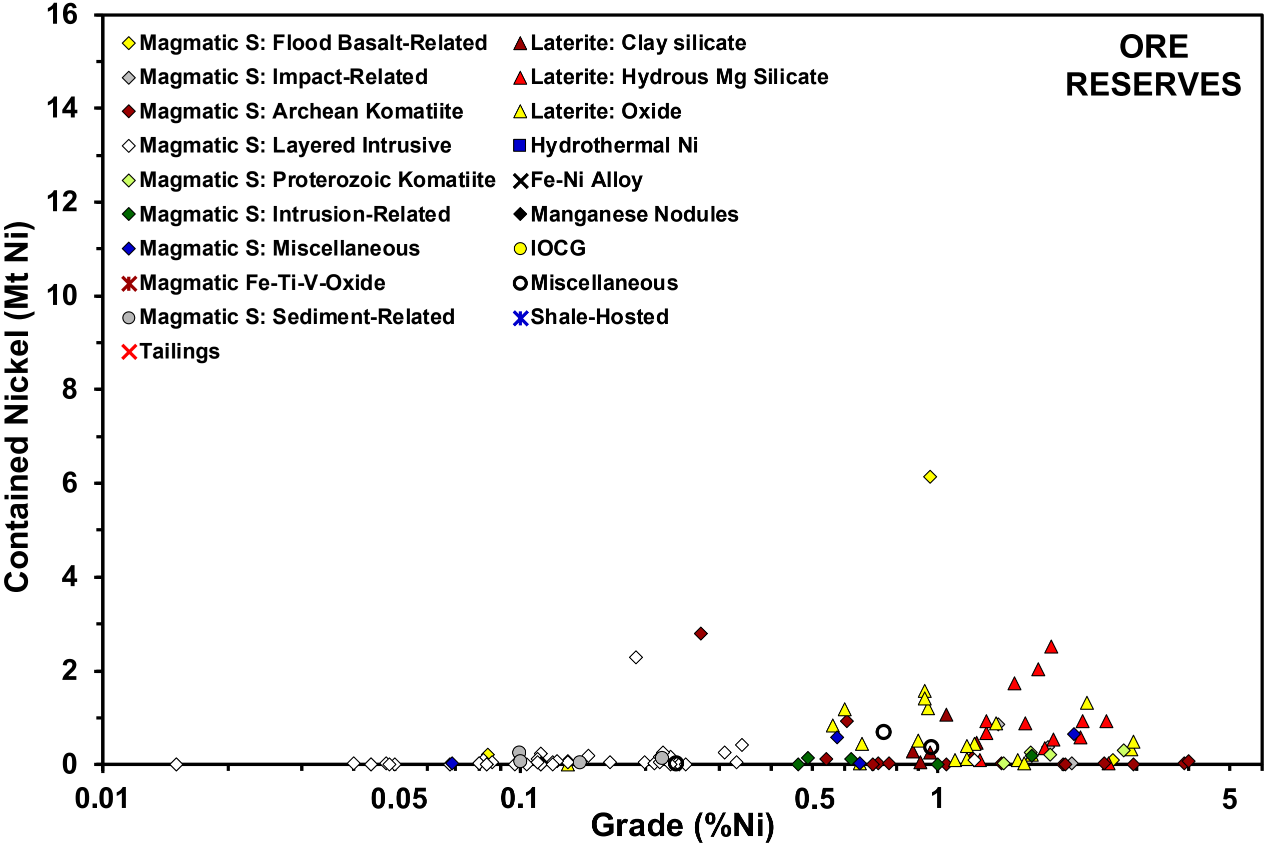
Global Nickel production by type



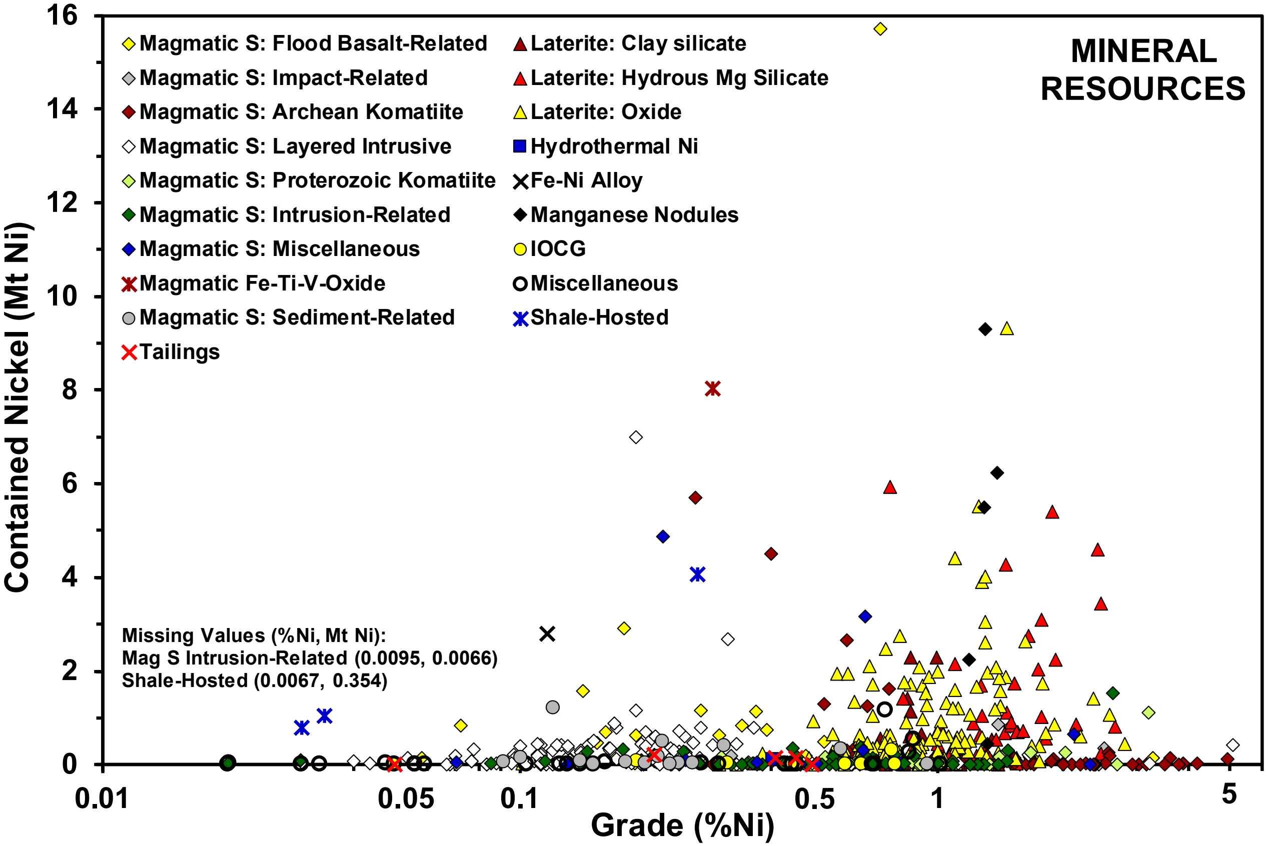
Global Nickel resources and reserves

- Identified 626 nickel deposits with in-ground resources and reserves, including 235 Ni laterite, 342 magmatic sulfide and 49 miscellaneous (e.g., hydrothermal, Ni alloy, seafloor Mn nodule, etc.) Ni-containing resources.
- Contain **350.3 Mt of contained Ni in resources** that, if all converted into resources and hence production, could meet ~106 years of Ni demand at current production rates (~3.3 Mt Ni) but does not include increased demand.
- **Global Ni reserves** contain some **47.12 Mt of Ni** split into 25.97, 20.14, and 1.01 Mt Ni in laterite, sulfide and miscellaneous reserves, respectively.
- Comparison to 2011 data indicate that magmatic sulfide deposits are keeping pace with depletion by mining
- Laterite resources and reserves are lower than in 2011, suggesting these near surface deposits can be more comprehensively assessed during the early stages of laterite resource and reserve estimation
- All of these values are global minima; poor reporting in some countries means some deposits likely missed
- Important to remember resources and reserves are **dynamic**

Global Nickel Reserves

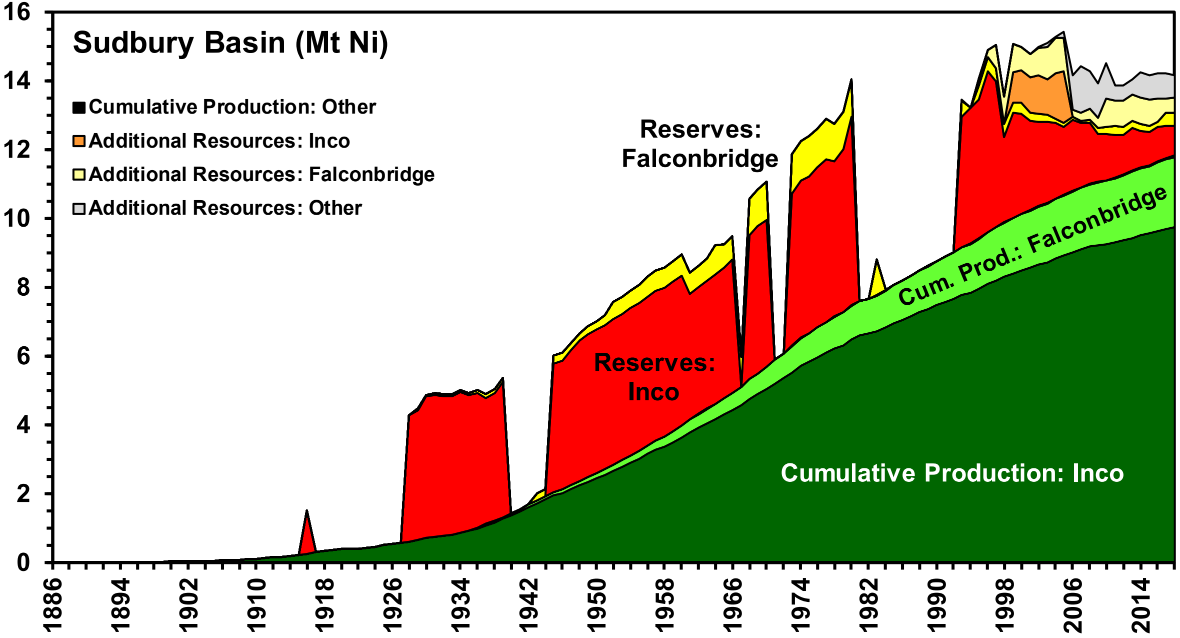


Global Nickel Resources



Current reserves and resources ≠ not all there is!

- After 134 years of mining, Sudbury still a major world Ni resource
- Mining camp controlled by Vale (Inco), Glencore (Falconbridge), plus small mines
- Highlights need to distinguish geology vs economics & raft of complex social & environmental issues; get it right = mining success
- Recent developments in Minnesota show impact of ESG challenges… but hard to judge!



Biden administration revokes Trump-approved Minnesota mining lease

A study that could lead to a 20-year ban on mining upstream from the Boundary Waters Canoe Area Wilderness was green lighted

Mining upstream from the Boundary Waters Canoe Area Wilderness could be banned for 20 years. Photograph: Prisma Bildagentur AG/Alamy

The Biden administration on Wednesday canceled a move by former president Donald Trump to renew mineral rights leases for a proposed Twin Metals copper-nickel mine in north-eastern Minnesota.

Trump had signed an order a month before the 2020 presidential election declaring a national emergency over the country's reliance on imported metals used to manufacture computers, smartphones, batteries for electric cars and other items.

The reversal by Biden on the two leases follows an October decision to move forward with a study that could lead to a 20-year ban on mining upstream from the Boundary Waters Canoe Area Wilderness.

Rio Tinto Explores Carbon Capture at Minnesota Mining Site with $2.2 M DOE Funding

FEBRUARY 15, 2022 BY DAVID WORFORD

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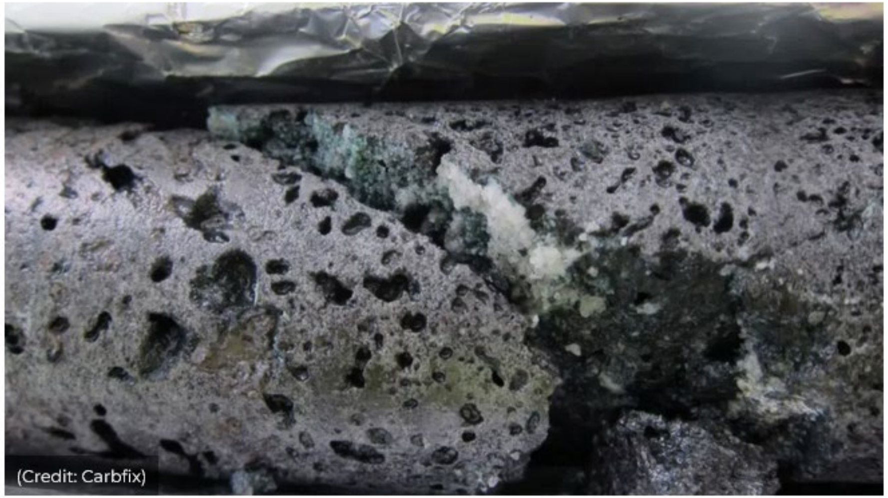
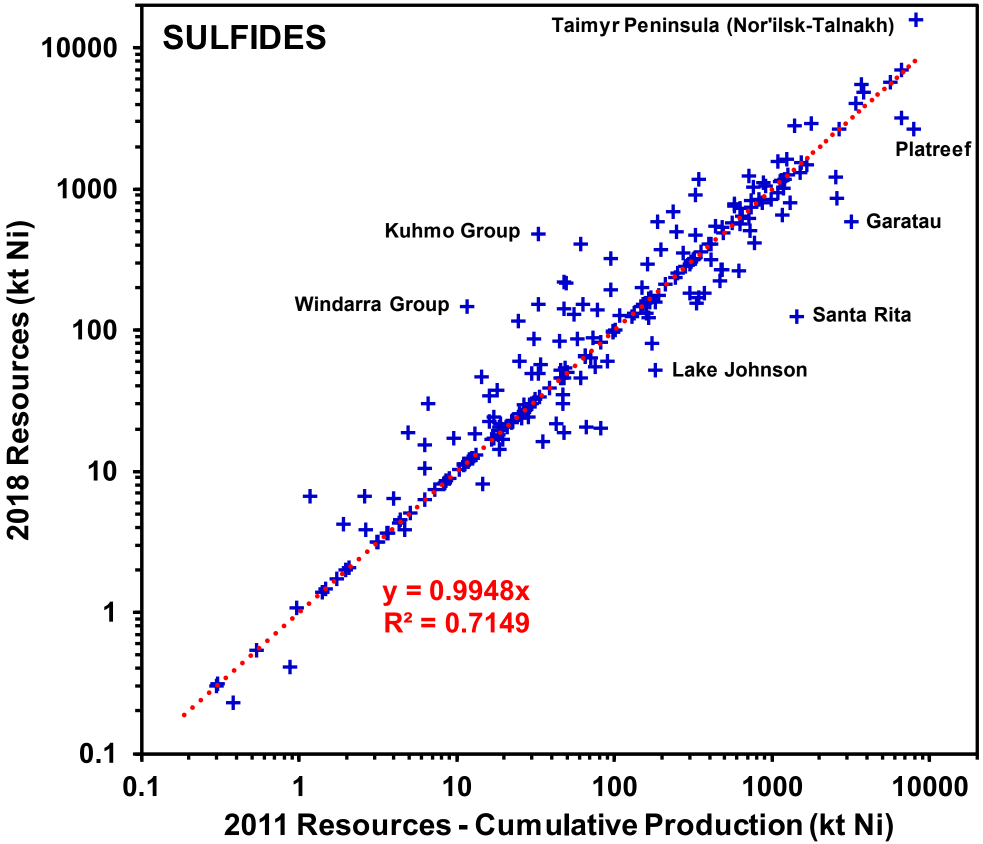


(Credit: Carbfix)

The US Department of Energy has awarded a Rio Tinto-led team $2.2 million in funding to explore carbon storage possibilities at the Tamarack Nickel Project site in Minnesota.

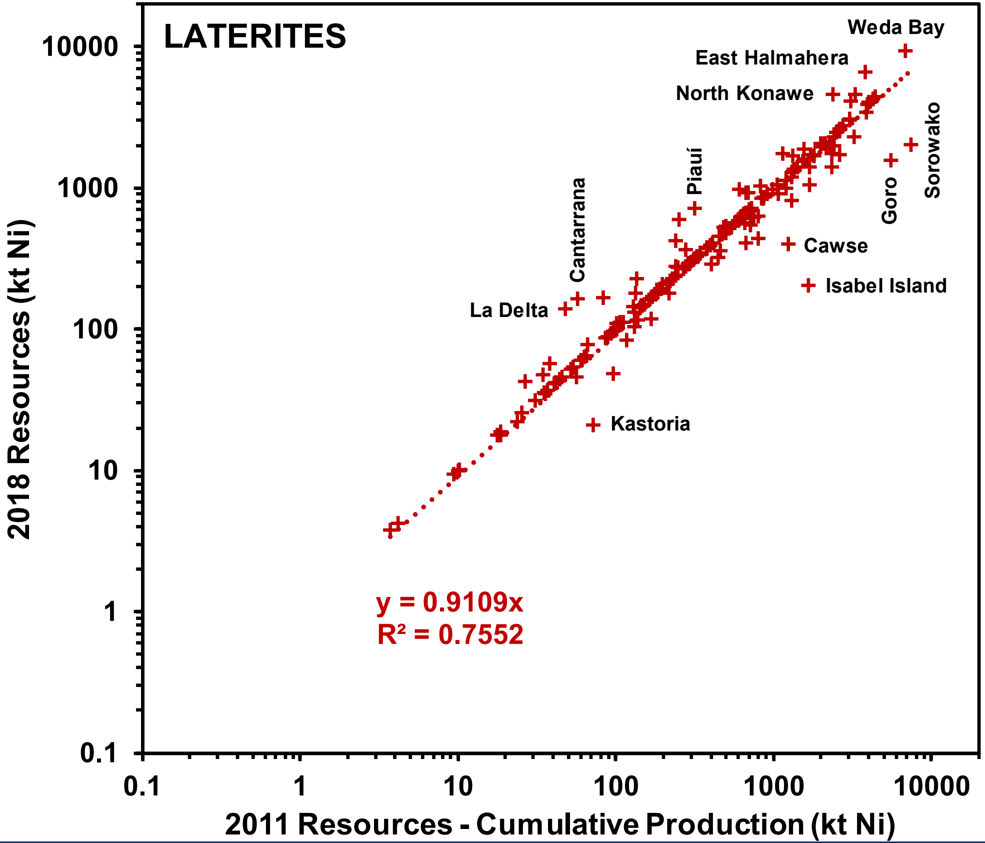
The team of climate and research professionals will study carbon mineralization technology as a way to store carbon as rock. The mining company Rio Tinto will add $4 million in funding toward the three-year project.

Change in resources over time coincident with production



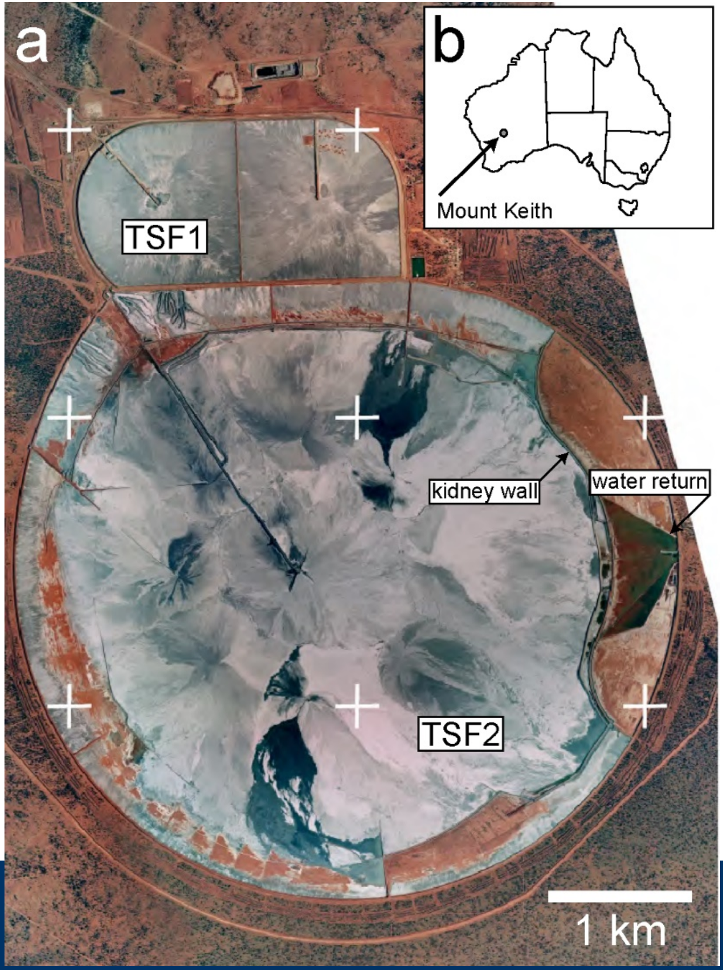
Change in resources over time coincident with production

- Sulfide resources typically **maintained** over time despite numerous projects producing nickel between 2011 and 2018
- Indicates brownfield expansion of resources keeping pace with production
- Laterite resources **decreasing** over time with production
- Suggests laterite resources more fully delineated early on in mining operations; **less scope for expansion**
- Both discovery and expansion can add nickel, but sustainability of latter varies by deposit type
- **Should be considered when modeling future changes in nickel supply**



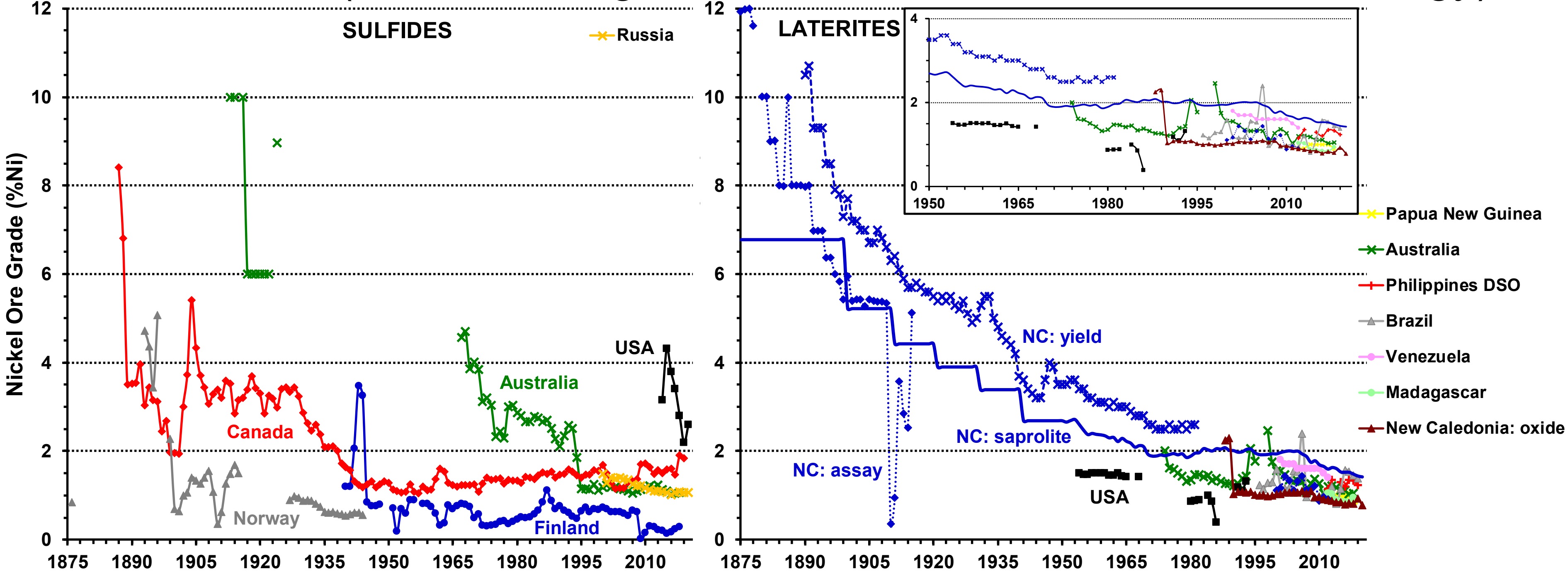
Other things to think about

- Mining of nickel sulfides from ultramafic rocks generates fine-grained waste suited for CO_2 sequestration
- E.g. Mt. Keith komatiite deposit, generates 11 Mt of serpentinite-dominated tailings per year; total resource >300 Mt
- ~39,800 t/yr of atmospheric CO_2 sequestered in tailings at Mt. Keith without enhanced sequestration; around 11% of CO_2 produced by minesite activities (Wilson et al., 2014)
- Probably the case for numerous other ultramafic-hosted Ni deposits; mining can effectively offset some CO_2 produced by mining
- Could be key for any move to carbon trading, meaning subeconomic Ni projects become economic



Other things to think about

- Decreasing grade equals increasing energy usage and CO_2 emissions (unless mining is electrified and uses renewable energy)

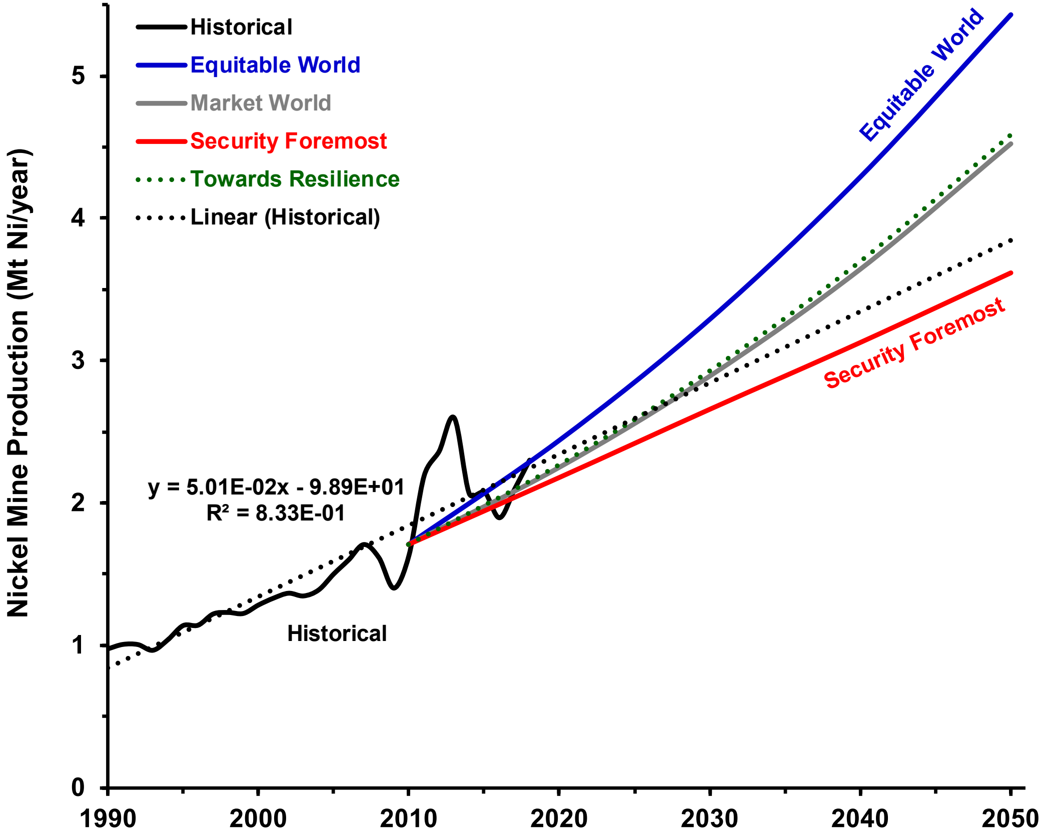


Other things to think about

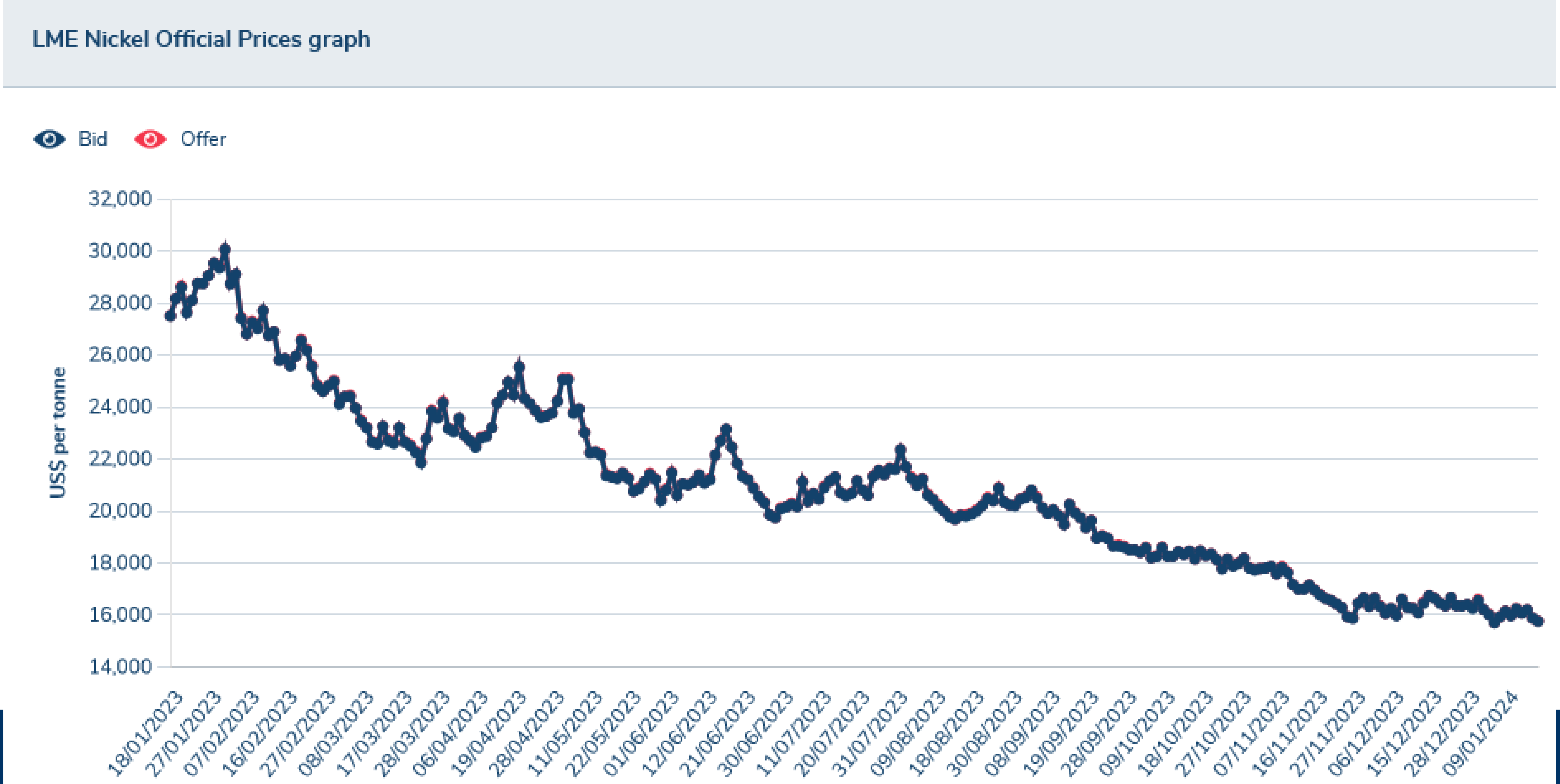
- Byproduct potential from nickel operations
- Co, Cu, PGE all well known and add value to mined ore (see Mudd and Jowitt, 2022, Econ Geol for detailed breakdowns)
- Significant other potential for byproducts from magmatic sulfide (e.g., Se, Te), potentially laterite (e.g., Sc), and unconventional nickel resources
- Key here is understanding potential and how these elements behave during mineral processing
- Worth investigating in some jurisdictions; e.g., US Federal tax breaks on critical metal production as a result of Inflation Reduction Act (IRA) of 2022
  - Advanced manufacturing tax credits in the IRA include one for the minerals industry; can write off 10 percent of the cost of your US operations as a tax credit if you produce any amount of “critical minerals” – nickel is one

Nickel demand models and uncertainty

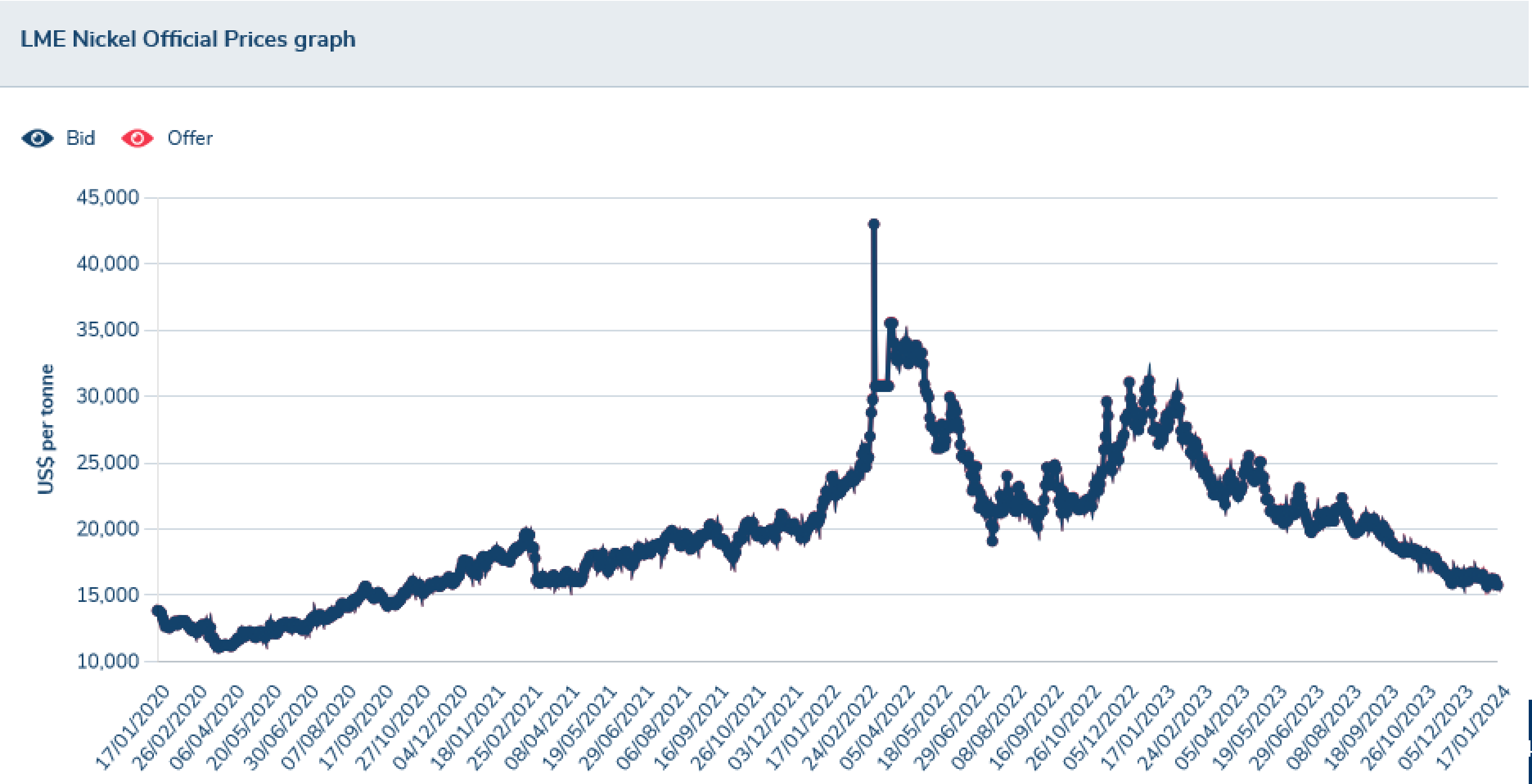
- Climate change mitigation and consumer and investor sentiment is increasing demand for renewable energy generation, energy storage and electric vehicles
- Generates increases in nickel demand that will continue for a significant period of time
- Model to right indicates implications for nickel production needed to meet this demand; nearly doubling
- However note production also ramped up to 3.3 Mt in 2023; oversupply?



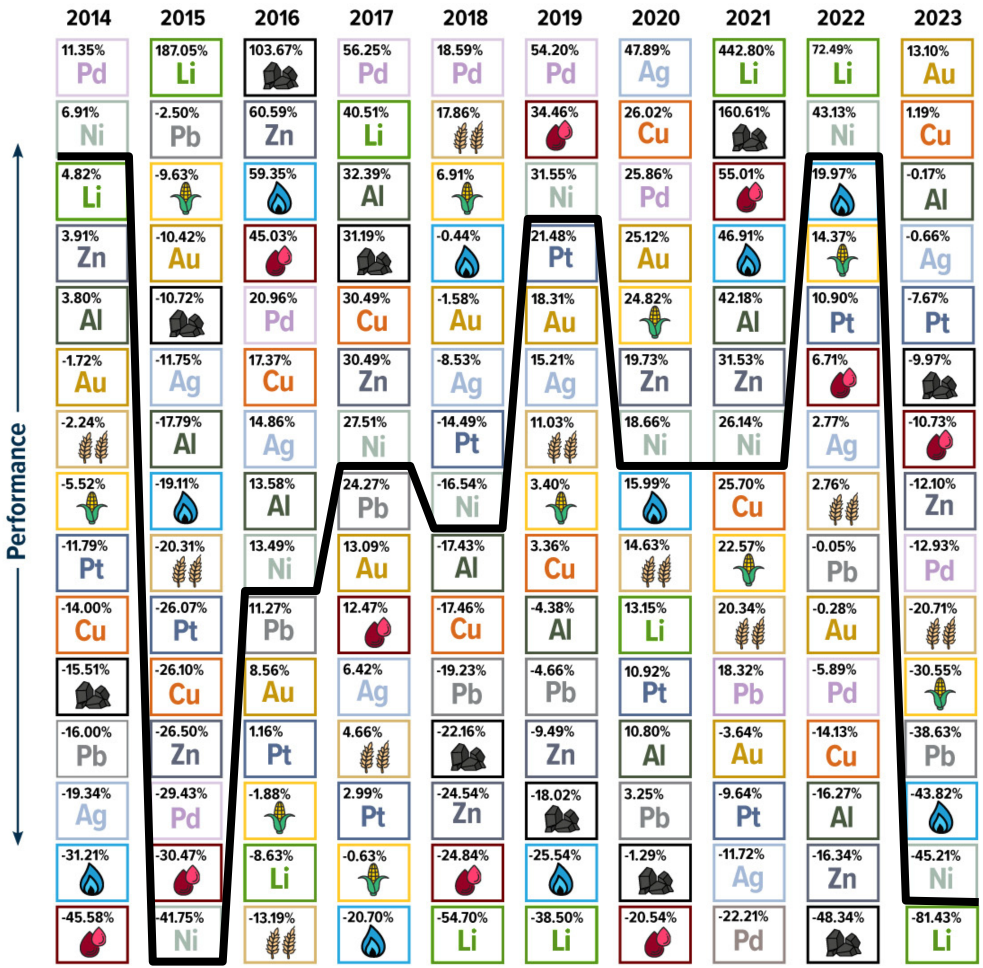
Nickel price 2023-2024; increased supply depressing prices?



Nickel price 2020-2024 – putting 2023 into context



Supply-demand imbalance and timing can cause volatility



Conclusions

- Overall, known nickel resources and reserves are sufficient to continue current levels of production for several decades (assuming all of this material can be mined and demand continues at the same level!)
- However, the nickel mining sector faces a number of challenges that may change this
- These include increased demand from the energy transition and potential supply restrictions relating to increased environmental, social, and governmental (ESG) challenges to the mining industry globally; e.g., can Indonesia sustain increased production?
- Increase in laterite supply good for overall nickel sector, perhaps not ideal for Class I battery needs without further (expensive?) refining?
- Means that although global nickel resources and reserves appear healthy and sufficient, rapid increases in demand, limitations on conversion of resources to reserves and production, and limited supplies of battery-ready nickel may cause significant supply issues
- Interesting times ahead…

Conclusions

- Could potentially see a nickel crunch scenario where nickel demand rapidly outpaces any potential increase in nickel supply, or even a shrinking of the latter (even with booming Indonesian supply right now)
- Especially true when considering Class I nickel; increasing proportion of nickel supply from laterites may not be ideal for battery manufacturing…?
- Potential for offset by positive developments in carbon credits for CO_2 sequestration by nickel mining operations (e.g., in ultramafic tailings) and the development of non-magmatic sulfide and non-laterite nickel resources
- Timing of demand increase is also uncertain, meaning that the nickel sector of the minerals industry may have time to develop and advance projects and overcome ESG challenges to meet this increase in demand
- However, the timing of supply increase can outpace demand – could cause short term but problematic price decreases that can cause challenging economics for nickel miners
- Real need to understand uncertainties in the nickel sector (and many other metal and mineral sectors) – including the influence of policy

Any questions?

- Email me at sjowitt@unr.edu
- Check out our 2022 Mudd and Jowitt paper in Economic Geology
- Happy to pass on papers, this powerpoint, our nickel deposit database and continue this discussion
- Many thanks to the Nickel Institute for funding some of this research

Nickel INSTITUTE
knowledge for a brighter future